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(10) William B. Lane
Lawrence D. Inman

Prepared for:

DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

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Generally, less than 10% of the activity was removed from SHASTA, JOHNIE BOY, or SEDAN fallout by either 0.1N HCl or water.

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By: WILLIAM B. LANE and LAWRENCE B. INMAN

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DEFENSE CIVIL PREPAREDNESS AGENCY
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I INTRODUCTION

Background

Synthetic fallout preparations for simulating selected properties of fallout are needed in laboratory and field experiments that are designed to evaluate radiological hazards and countermeasure procedures. For example, radioactive tagged particles with a given range in diameters have been produced for use in investigations of the effectiveness with which proposed decontamination methods remove fallout particles from surfaces.[1*] In such experiments, the radionuclide is bonded to the particles as a particle tracer so that the measured ratio of the dose rate before and after decontamination can be utilized directly to determine the effectiveness of the method in removing the fallout particles. However, in real fallout, some of the nuclides would be soluble, and these nuclides, carried by fallout particles that fall onto surfaces and are later exposed to conditions of dew and rain, would tend to be leached from the fallout particle and adsorbed by the surfaces.[2] After adsorption, all radioelements generally are not removed in decontamination processes as readily as the fallout particles; thus, consideration of the soluble nuclides in decontamination experiments is required to obtain reliable decontamination effectiveness values from such experiments.

Primary interest in the long-term effects of fallout is related to the fact that consumption of contaminated food produces an internal radiological hazard. The uptake of radionuclides by plants through their root

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*References are listed at the end of this report.

systems would be the principal path of food contamination in the long-term period after a nuclear war. However, at early times after such a war, the soluble nuclides from fallout particles could also be assimilated directly by the leaves and fruit of growing plants.

When contaminated food is consumed by animals and humans, the soluble radionuclides dissolve in the stomach fluids, and some fraction of each passes into the blood stream and thence to other body organs. The remainder, along with the insoluble nuclides, stays with the particles and passes through the digestive tract.

Thus, fallout simulants with a given degree of radionuclide solubility are needed for use in experimental studies of contamination of water sources and radionuclide cycling in the food chain.

Only very limited data on nuclide solubility of real fallout are available. The basic particle matrix of the fallout from nuclear test detonations has been either Nevada soil or Pacific atoll coral. In most of the solubility experiments on these materials, the activity measurements were made only on the total activity that dissolved into test solutions, rather than on amounts of individual nuclides that dissolved. In a hearing before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy,[3] the following percentages of radioactivity soluble in water were given: (1) for long-range fallout in Great Britain, 50 percent soluble; (2) for fallout from Nevada tower shots--particles less than 44 micorns, less than 2 percent soluble, and particles greater than 44 microns, less than 1 percent soluble; and (3) for fallout particles less than 44 microns from Nevada Operation Jangle underground shots, 5 percent soluble. The soluble activity fraction was given as 60-90 percent in Operation Castle[4] and 20 percent in Operation Redwing.[5] In some cases the fractions refer to beta count-rate ratios, and in others they refer to gamma count-rate ratios. Further, these results apply to specific

samples of fallout and to specific, but variable, times after detonation. Unfortunately, the general problems of radionuclide cycling in food chains, water contamination, and decontamination require more precise information on solubility, leaching, and exchange processes than can be deduced from such data as the above.

Because of the general lack of reliable solubility data on real fallout, models[6] were developed to provide approximate descriptions of fallout particle properties, such as nuclide solubility, through specifications of basic dependent parameters (contour ratios) in terms of the ratio of density factor for a given property of the fallout particles to the standard intensity (r/hr at one hour). The density of the desired fallout property is then obtained by multiplying the contour ratio by the standard intensity. The currently available radioelement solubility model for a land surface detonation[7] assumes that the fraction of an element that condenses on the exterior of a solid particle is potentially soluble and biologically available. Norman and his coworkers[8] at Gulf General Atomics have investigated the high temperature diffusion of certain elements in mineral systems; however, no method has yet been developed to relate the diffusion data to biological availability.

Approach

As an approach to this problem, leaching experiments--using heat-treated synthetic fallout and real fallout--were conducted. Upon the disestablishment of the Naval Radiological Defense Laboratory (NRDL) in 1969, SRI took custody of a number of field samples collected at SHASTA, SMALL BOY, JOHNIE BOY, and SEDAN. Many of these samples were stored in sealed containers and their history was well documented. Long-term leaching studies were started with synthetic fallout in 1967 and with each of the four nuclear tests in 1968 and 1969 by subjecting the radioactive mineral particles to leaching by 0.1$\underline{N}$ HCl (to represent stomach acid) and

distilled water. Each fallout sample was successively leached by fresh aliquots of the leachant so the combined results could be used to describe the leaching process. Results of these tests were previously reported in 1969[9] and in 1970.[10]

The leaching of Cs-134 from synthetic fallout was shown to be described by two mechanisms:[9] initial leaching (10 days) was controlled by an adsorption reaction, while long-term leaching (up to 750 days) was controlled by a diffusion process. As temperatures of the thermal treatment were increased, the overall availability of Cs-134 was decreased, although there was no difference in the diffusion from synthetic fallout heated to 900°C and 1200°C. Fallout from SHASTA had a very small fraction of available radionuclides (1-5 percent) as measured after 615 days of leaching. Fallout from SMALL BOY, JOHNIE BOY, and SEDAN were similarly leached and the results from the first 160 days reported.[10] Leaching of SMALL BOY fallout by 0.1<u>N</u> HCl removed 60 percent of the activity from large particles, while leaching by water removed only a few percent of the activity. Generally, less than 10 percent of the activity was removed from JOHNIE BOY or SEDAN fallout by either 0.1<u>N</u> HCl or water.

The first part of this report describes the results of continuing the Cs-134, SHASTA, SMALL BOY, JOHNIE BOY, and SEDAN leaching for several years. Gamma spectroscopy using a lithium-drifted germanium diode detector and a 1024 channel spectrometer permits the analysis of leached fallout samples to be reported in terms of individual fission-product radionuclides, instead of in terms of gross gamma counting as was reported earlier.[9,10]

The second part of this report describes the production of synthetic fallout for DCPA contractors. Over the years, procedures to simulate many properties of real fallout have been developed and reported.[11,12,13] These procedures have been used in the hot-cell facility at Camp Parks to prepare batches of synthetic fallout for investigators at NRDL, Cornell University,

Oak Ridge National Laboratory, University of Tennessee, University of California, Lawrence Radiation Laboratory, Colorado State University, University of North Carolina, and SRI, which have all used synthetic fallout prepared to their specifications.

II EXPERIMENTAL DETAILS

Real Fallout and Synthetic Fallout Leaching Experiment

Samples

SMALL BOY was a near surface burst in the low kiloton range, JOHNIE BOY was a surface burst in the low kiloton range, and SEDAN was an underground detonation in the 100 kiloton range. SHASTA was a tower shot of 17 kilotons. Close-in fallout from each of these tests was collected at the Nevada Test Site in 1962, and many samples have been stored in the original sealed containers at Camp Parks. Particles of fallout from each of these nuclear events were obtained from the inventory by opening the following samples:

SMALL BOY	Sample 100P01
JOHNIE BOY	Sample 01-2
SEDAN	Sample 7
SHASTA	Tarp Sample

Radiochemical properties of the selected fallout particles were documented in 1962 and can be found in References 14, 15, and 16.

Investigators at Oak Ridge National Laboratory requested a synthetic fallout for an ecological study to measure the effects of Cs-137 on a controlled ecological system over a period of years. A preliminary experiment was desired to define some of the parameters, and three 7 lb batches of synthetic fallout tagged with about 1 microcurie of Cs-134 per gram were produced for them. Two grams of each batch was used for leaching.

Procedures

Long-term tests were initiated to measure leaching at extreme dilutions. This was accomplished by adding a 20 ml aliquot of leachant to a measured weight of particles in a 40 ml centrifuge tube. The following day the tube was centrifuged and the clear leachant decanted into another, similar 40 ml tube. A second 20 ml of the same leachant was immediately added to the tube containing the particles. The process of leaching the same fallout particles with fresh aliquots was continued for many years. To date, aliquots of leachants were accumulated over time periods, as shown in Table 1.

SMALL BOY sample 100P01 and JOHNIE BOY sample 01-2 were sieved, and the 16 recovered sieve fractions were leached as shown in Table 2. SEDAN sample 7 was a very large gross sample of many pounds, and 100 grams of it was sieved to provide 7 fractions of fallout as shown in Table 2.

Particles of fallout from SHASTA were separated into magnetic and nonmagnetic fractions by letting the particles fall through a plastic tube between the poles of a large permanent magnet. The particles that fell through the tube were arbitrarily classified as nonmagnetic and those that were retained were classified as magnetic.

The magnetic and nonmagnetic fractions from SHASTA were sieved, weighed, and measured in the well-crystal counter. The data are presented in Table 3 along with the specific activity as measured on 16 January 1968.

Since the mass and activity were both concentrated in the large sizes in this particular SHASTA fallout, leaching tests were limited to particles in the 500-1000 micron diameter size range. Table 4 shows the sample weights and leachants used in the tests.

Table 1

LEACHING TIME INTERVALS

	Cs-134			SHASTA			SMALL BOY, SEDAN, JOHNIE BOY		
Aliquot	Date	Δ Time* (days)	Σ Time† (days)	Date	Δ Time* (days)	Σ Time† (days)	Date	Δ Time* (days)	Σ Time† (days)
Mineral	6 Feb 67	0	0	16 Jan 68	0	0	11 Nov 69	0	0
1	7 Feb 67	1	1	18 Jan 68	2	2	12 Nov 69	1	1
2	8 Feb 67	1	2	22 Jan 68	4	6	13 Nov 69	1	2
3	9 Feb 67	1	3	12 Feb 68	21	27	14 Nov 69	1	3
4	10 Feb 67	1	4	26 Mar 68	43	70	20 Nov 69	6	9
5	13 Feb 67	3	7	10 Jun 68	76	146	24 Nov 69	4	13
6	15 Feb 67	2	9	26 Sep 68	108	254	15 Dec 69	21	34
7	20 Feb 67	5	14	23 Dec 68	88	342	23 Jan 70	39	73
8	2 Mar 67	10	24	21 Jan 69	29	371	20 Apr 70	87	160
9	4 Mar 67	2	26	10 Sep 69	232	603	28 Aug 70	130	290
10	6 Mar 67	2	28	23 Jan 70	135	738	15 Jan 71	140	430
11	8 Mar 67	2	30	20 Apr 70	87	825	5 May 71	110	540
12	28 Mar 67	20	50	28 Apr 70	8	833	23 Feb 72	294	834
13	11 Apr 67	14	64	15 Jan 71	262	1,095	18 Jan 73	330	1,164
14	5 May 67	24	88	5 May 71	110	1,205	17 Jan 75	729	1,893
15	20 Jun 67	46	134	23 Feb 72	294	1,499			
16	14 Jul 67	24	158	18 Jan 73	330	1,829			
17	15 Aug 67	32	190	17 Jan 75	729	2,558			
18	26 Sep 67	42	232						
19	27 Oct 67	31	263						
20	3 Jan 68	68	331						
21	12 Feb 68	40	371						
22	22 Mar 68	43	414						
23	10 Jun 68	76	490						
24	20 Sep 68	102	592						
25	23 Dec 68	94	686						
26	20 Jan 69	28	714						
27	25 Feb 69	36	750						
28	23 Jan 70	332	1,082						
29	20 Apr 70	87	1,169						
30	28 Apr 70	8	1,177						
31	15 Jan 71	262	1,439						
32	5 May 71	110	1,549						
33	23 Feb 72	294	1,843						
34	18 Jan 73	330	2,173						
35	22 Apr 75	822	2,995						

*Days at leaching for specified aliquot.

†Accumulated days that mineral was leached.

Table 2

MINERAL PARTICLES IN NEVADA FALLOUT LEACHING TESTS

Particle Size (micron)	SMALL BOY Weight (g)	SMALL BOY Leachant (20 ml)	JOHNIE BOY Weight (g)	JOHNIE BOY Leachant (20 ml)	SEDAN Weight (g)	SEDAN Leachant (20 ml)
> 2830			1.8	0.1$\underline{N}$		
2830-1410	0.267	0.1$\underline{N}$	1.9	HOH	2.0	0.1$\underline{N}$
1410- 710	0.345	HOH	2.8	0.1$\underline{N}$	2.0	0.1$\underline{N}$
710- 350	0.225	0.1$\underline{N}$	2.6	HOH	2.0	0.1$\underline{N}$
350- 177	0.667	HOH	3.4	0.1$\underline{N}$	2.0	0.1$\underline{N}$,H_2O
177- 88	0.177	0.1$\underline{N}$	4.9	HOH	2.0	0.1$\underline{N}$,H_2O
88- 44	0.405	HOH	--		2.0	0.1$\underline{N}$,H_2O
88- 62	--		2.1	0.1$\underline{N}$	--	
62- 44	--		1.6	HOH	--	
< 44	0.338	0.1$\underline{N}$	1.7	0.1$\underline{N}$	2.0	0.1$\underline{N}$,H_2O

Table 3

SIZE AND ACTIVITY DISTRIBUTIONS IN SHASTA FALLOUT PARTICLES

Counted 16 January 1968
Background 378 c/m
Standard 44006 c/m

	Particle Diameter (micron)	Weight (g)	Activity Sample (c/m)	Specific Activity* (c/m/g)
Magnetic				
	500-1000	0.5149	139,717	270,600
	250- 500	0.0412	2,445	50,170
	105- 250	0.2311	5,279	21,210
	47- 105	0.0754	4,441	53,880
	< 47	0.0105	2,036	157,900
Nonmagnetic				
	500-1000	4.0712	284,500	60,970
	250- 500	2.0480	2,355	964
	105- 250	1.7078	1,477	643
	47- 105	0.0882	832	5,147
	< 47	0.0290	2,633	77,760

*Gross gamma counts per minute per gram.

Table 4

LEACHANTS USED IN SHASTA FALLOUT TESTS

Type	Weight (g)	Leachant
Magnetic	0.1174	Successive 20 ml water
Magnetic	0.1000	Successive 20 ml 0.1N HCl
Nonmagnetic	0.4865	Successive 20 ml water
Nonmagnetic	0.4995	Successive 20 ml 0.1N HCl

Synthetic fallout was prepared by surface adsorption of Cs-134 on mineral particles from a carrier solution containing stable atoms of major fissions' product elements. Element concentrations in the carrier solution were based on 2×10^{14} fissions being associated with 1 gram of fallout. Seven-pound batches of mineral particles of Wedron sand between 88 and 175 micron diameter were placed in a rotating mixer and sprayed with carrier solution containing Cs-134. After drying in a stream of warm air, one batch was heated to 900°C for one hour, a second batch was heated to 1200°C for one hour, and the third batch was retained in the air-dried condition. Each batch was sampled and assayed, and its solubility, as shown in Table 5, was determined on the basis of overnight leaching of 2 grams of the synthetic fallout by 20 ml of 0.1N HCl.

Since the Oak Ridge study was designed to continue for several years, leaching data covering a few hours seemed inadequate to predict the availability of cesium. Accordingly, long-term tests were initiated to measure the leaching of Cs-134 at extreme dilutions. This was accomplished by setting aside the 20 ml aliquot of 0.1N HCl that resulted from overnight leaching and adding a second, similar aliquot to the once-leached synthetic fallout. This process of leaching the same mineral fraction for random time intervals with fresh aliquots was continued for 2,995 days and resulted in the accumulation of 35 successive leaching aliquots.

Table 5

PROPERTIES OF Cs-134 SYNTHETIC FALLOUT

Batch	Temperature (°C)	Specific Activity* (μCi/g)	Fraction Removed (percent)
1	20	1.31	60.6
2	900	1.34	17.6
3	1200	2.09	4.34

*Specific activity determined by assay on 6 February 1967.

Radionuclide Measurement

The long-term leaching tests of Nevada fallout were terminated on 17 January 1975 and the synthetic fallout tests on 22 April 1975. All mineral particles and leach aliquots were oven-dried prior to counting. A special jig was provided for counting the 40 ml conical centrifuge tubes in a fixed position to insure a constant geometry for all radioactivity measurements.

Pulse height measurements were made with a gamma spectrometer using an Ortec lithium-drifted germanium diode detector, and a Canberra 1024 channel analyzer. The output from the spectrometer was connected to both a teletype printer-paper tape unit and an x-y plotter.

The activity in counts per minute (c/m) of each nuclide was determined by integrating the area under that nuclide's most prominent gamma ray peak.

The efficiency (in counts per disintegration) was determined for each of the nuclides to enable a calculation of number of atoms and equivalent fissions per gram.

III RESULTS AND DISCUSSION

Gamma spectroscopy with a Lithium drifted Germanium diode detector makes possible the interpretation of fission-product activity measurements in terms of individual radionuclides. These quantitative results permit some pertinent observations about the leaching process. The results also show differences among the nuclear shots SMALL BOY, JOHNIE BOY, SEDAN, and SHASTA. Variations from the theoretical[17] composition and concentrations of the nuclides in fallout are demonstrated.

Leaching of SMALL BOY Fallout

A count rate vs energy plot of a typical spectra of leached mineral and leach aliquots is shown in Figure 1. The fission-product nuclides Cs-137 at 661 kev, Sb-125 at 427 kev, and Eu-155 at 85 kev are positively identified as well as the neutron activation product Eu-152 at 343 kev. Other, less prominent, peaks are also marked and are characteristic for the indicated radionuclides.

The area under the peak, from valley to peak to valley, was determined from the digital printout, and this gave a sample activity in counts per minute for each of the nuclides, as shown in Tables 6-12. The mineral activity at the time of individual leach intervals was equal to the final mineral activity plus the sum of all the activity that was previously leached. This permitted the calculation of nuclide concentration in the mineral, C_m, and in the liquid, C_ℓ, at the end of each leaching interval. The fraction of the initial activity, C_o, that remained was then C_m/C_o. These values are also presented in Tables 6-12.

The availability of a nuclide for leaching from a fallout particle may represent the degree to which the nuclide forms a solid or liquid solution at a given temperature, the dissolved atoms may become immobilized in

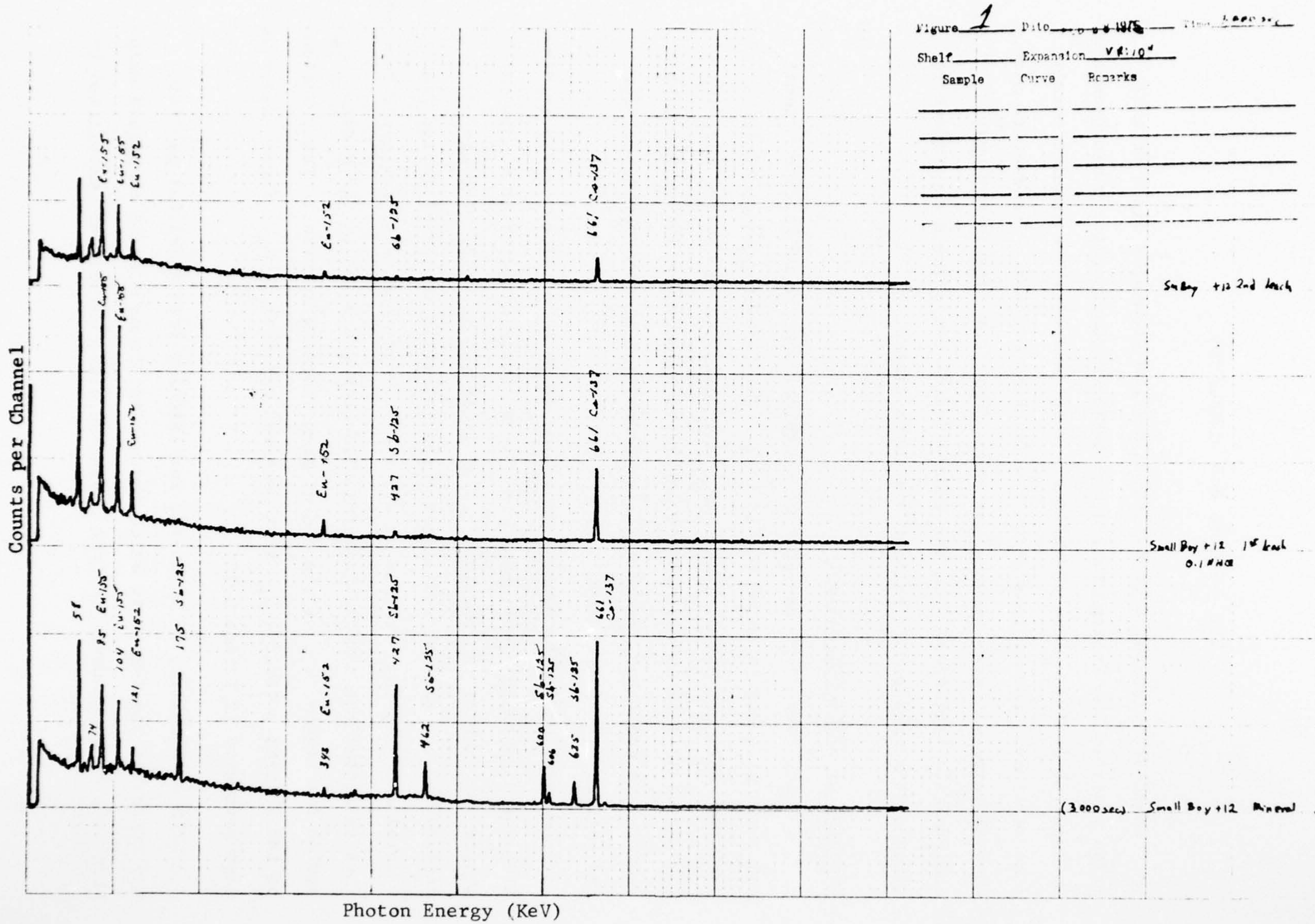

Figure 1. Count Rate vs Energy Plot of a Typical Leached Mineral and Leach Aliquot Spectra.

the structure of the mineral particle. The mechanism for this phenomenon may entail a diffusion and chemical reaction (solution or compound formation), as well as adsorption.

Freundlich derived an empirical expression for the adsorption of a gas by a solid, which has since been used to describe many adsorption reactions, including the chemisorption and ion exchange reactions in soil minerals.[18] Leaching of cesium from the three types of synthetic fallout was investigated through the Freundlich equation, given by

$$C_m = kC_\ell^n \tag{1}$$

where C_m and C_ℓ are as defined previously and k and n are equation constants. The first few aliquots, extending out to several days' leaching, showed a good fit to the Freundlich expression, and equation constants were reported in Reference 9. No attempt was made to repeat the Freundlich fit for this report; however, the data in Table 6 are complete for an evaluation of the equation constants k and n.

Plotting values of C_m and C_ℓ from later leaching aliquots (after several days) showed that the chemisorption process as described by the Freundlich equation was no longer controlling the leaching of cesium from the synthetic fallout, and a diffusion limiting mechanism was then investigated using Fick's law, as

$$\frac{C_m}{C_o} = \frac{6}{\pi^2} \sum_{1}^{\infty} \exp\left[- \nu^2 \pi^2 Dt/r_o^2\right] \tag{2}$$

where

C_o is the initial Cs-134 concentration

C_m is the Cs-134 concentration after various leaching times

t is the time of leaching

r_o is the radius of the fallout particle

D is the diffusion coefficient

The first term of the series is a good approximation when t is sufficiently large, thus

$$\frac{C_m}{C_o} \approx \frac{6}{\pi^2} \exp\left[-t/\tau\right] \tag{3}$$

where

$\tau = r_o^2/\pi^2 D$

and equation (3) can be written

$$\log\left(C_m/C_o\right) = -\frac{1}{\tau}t + k \tag{4}$$

In Reference 9 a plot of $\log(C_m/C_o)$ and time showed that the leaching process after a few days was controlled by a leaching mechanism. Straight line portions of the curves permitted a solution for the diffusion coefficient, D, using the slope, $1/\tau$, and an assigned particle diameter.

The SMALL BOY data presented in Tables 6 through 12 were tested according to equation 4, and the plots are presented in Figures 2-29. The straight line was obtained by running a least square fit on the four last points.

Table 6

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 2830 - 1410 MICRONS
COUNTING DATE 4 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .550 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.267 GM)			27.20	2092.92		
1 LEACH OF 20 ML	1	1	54.860	1889.51	2.7155	.9028
2 LEACH OF 20 ML	1	2	20.300	1815.54	.9875	.8675
3 LEACH OF 20 ML	1	3	50.000	1630.34	2.4725	.7790
4 LEACH OF 20 ML	6	9	170.840	992.55	8.5145	.4742
5 LEACH OF 20 ML	4	13	97.620	628.99	4.8535	.3005
6 LEACH OF 20 ML	21	34	91.100	289.85	4.5275	.1385
7 LEACH OF 20 ML	39	73	17.820	225.17	.8635	.1076
8 LEACH OF 20 ML	87	160	5.680	205.96	.2565	.0984
9 LEACH OF 20 ML	130	290	6.980	181.87	.3215	.0869
10 LEACH OF 20 ML	140	430	6.980	157.79	.3215	.0754
11 LEACH OF 20 ML	110	540	3.300	147.49	.1375	.0705
12 LEACH OF 20 ML	294	834	6.320	125.88	.2885	.0601
13 LEACH OF 20 ML	330	1164	2.680	117.90	.1065	.0563
14 LEACH OF 20 ML	729	1893	5.380	99.81	.2415	.0477

BACKGROUND .160
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.267 GM)			4.10	148.31		
1 LEACH OF 20 ML	1	1	4.600	131.69	.2220	.8879
2 LEACH OF 20 ML	1	2	2.360	123.45	.1100	.8323
3 LEACH OF 20 ML	1	3	3.660	110.34	.1750	.7439
4 LEACH OF 20 ML	6	9	10.160	72.88	.5000	.4914
5 LEACH OF 20 ML	4	13	5.100	54.38	.2470	.3667
6 LEACH OF 20 ML	21	34	3.860	40.52	.1850	.2732
7 LEACH OF 20 ML	39	73	.740	38.35	.0290	.2586
8 LEACH OF 20 ML	87	160	1.220	34.38	.0530	.2318
9 LEACH OF 20 ML	130	290	1.660	28.76	.0750	.1939
10 LEACH OF 20 ML	140	430	2.220	21.05	.1030	.1419
11 LEACH OF 20 ML	110	540	.540	19.63	.0190	.1323
12 LEACH OF 20 ML	294	834	.160	19.63	0.0000	.1323
13 LEACH OF 20 ML	330	1164	.900	16.85	.0370	.1136
14 LEACH OF 20 ML	729	1893	.720	14.76	.0280	.0995

Table 6 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL — STANDARD 40000.000 C/M
THERMAL TREATMENT 20 C — BACKGROUND .040 C/M
PARTICLE SIZE 2830 - 1410 MICRONS — LEACHING STARTED 11 NOV. 1969
COUNTING DATE 4 MAR. 1975

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.267 GM)			31.90	177.83		
1 LEACH OF 20 ML	1	1	1.900	170.86	.0930	.9608
2 LEACH OF 20 ML	1	2	1.020	167.19	.0490	.9402
3 LEACH OF 20 ML	1	3	1.480	161.80	.0720	.9099
4 LEACH OF 20 ML	6	9	4.580	144.79	.2270	.8142
5 LEACH OF 20 ML	4	13	2.780	134.53	.1370	.7565
6 LEACH OF 20 ML	21	34	.460	132.96	.0210	.7477
7 LEACH OF 20 ML	39	73	1.020	129.29	.0490	.7270
8 LEACH OF 20 ML	87	160	.340	128.16	.0150	.7207
9 LEACH OF 20 ML	130	290	.540	126.29	.0250	.7102
10 LEACH OF 20 ML	140	430	.200	125.69	.0080	.7068
11 LEACH OF 20 ML	110	540	.420	124.27	.0190	.6988
12 LEACH OF 20 ML	294	834	.360	123.07	.0160	.6921
13 LEACH OF 20 ML	330	1164	.440	121.57	.0200	.6837
14 LEACH OF 20 ML	729	1893	.640	119.33	.0300	.6710

BACKGROUND .693
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.267 GM)			55.70	1559.27		
1 LEACH OF 20 ML	1	1	24.520	1470.03	1.1913	.9428
2 LEACH OF 20 ML	1	2	8.760	1439.82	.4033	.9234
3 LEACH OF 20 ML	1	3	23.280	1355.22	1.1293	.8691
4 LEACH OF 20 ML	6	9	60.480	1131.30	2.9893	.7255
5 LEACH OF 20 ML	4	13	43.980	969.18	2.1643	.6216
6 LEACH OF 20 ML	21	34	54.860	766.30	2.7083	.4915
7 LEACH OF 20 ML	39	73	35.000	637.81	1.7153	.4090
8 LEACH OF 20 ML	87	160	33.640	514.42	1.6473	.3299
9 LEACH OF 20 ML	130	290	37.120	377.99	1.8213	.2424
10 LEACH OF 20 ML	140	430	14.760	325.30	.7033	.2086
11 LEACH OF 20 ML	110	540	9.460	292.46	.4383	.1876
12 LEACH OF 20 ML	294	834	9.820	258.28	.4563	.1656
13 LEACH OF 20 ML	330	1164	8.260	229.94	.3783	.1475
14 LEACH OF 20 ML	729	1893	7.080	206.02	.3194	.1321

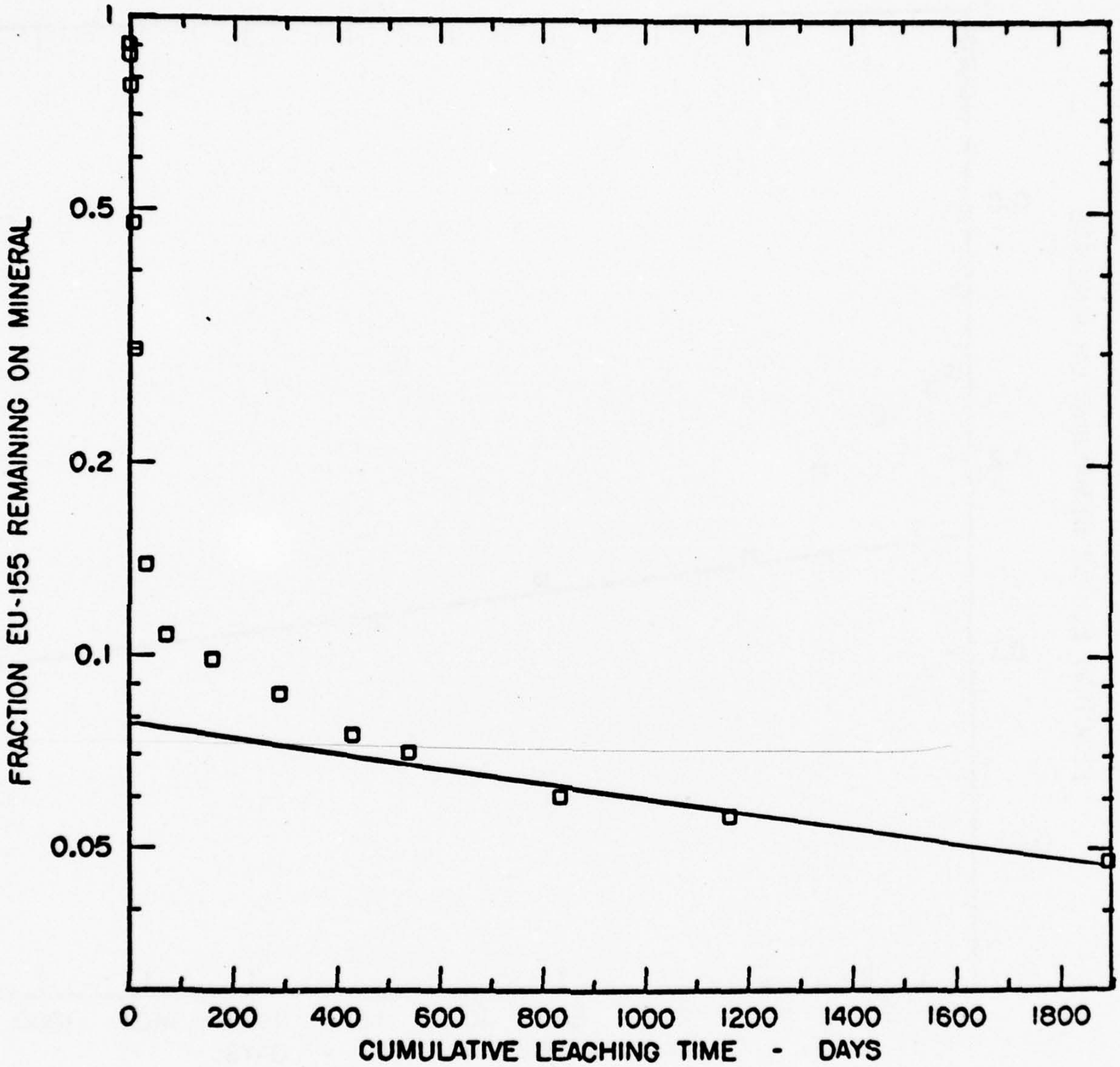

Figure 2. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 6.

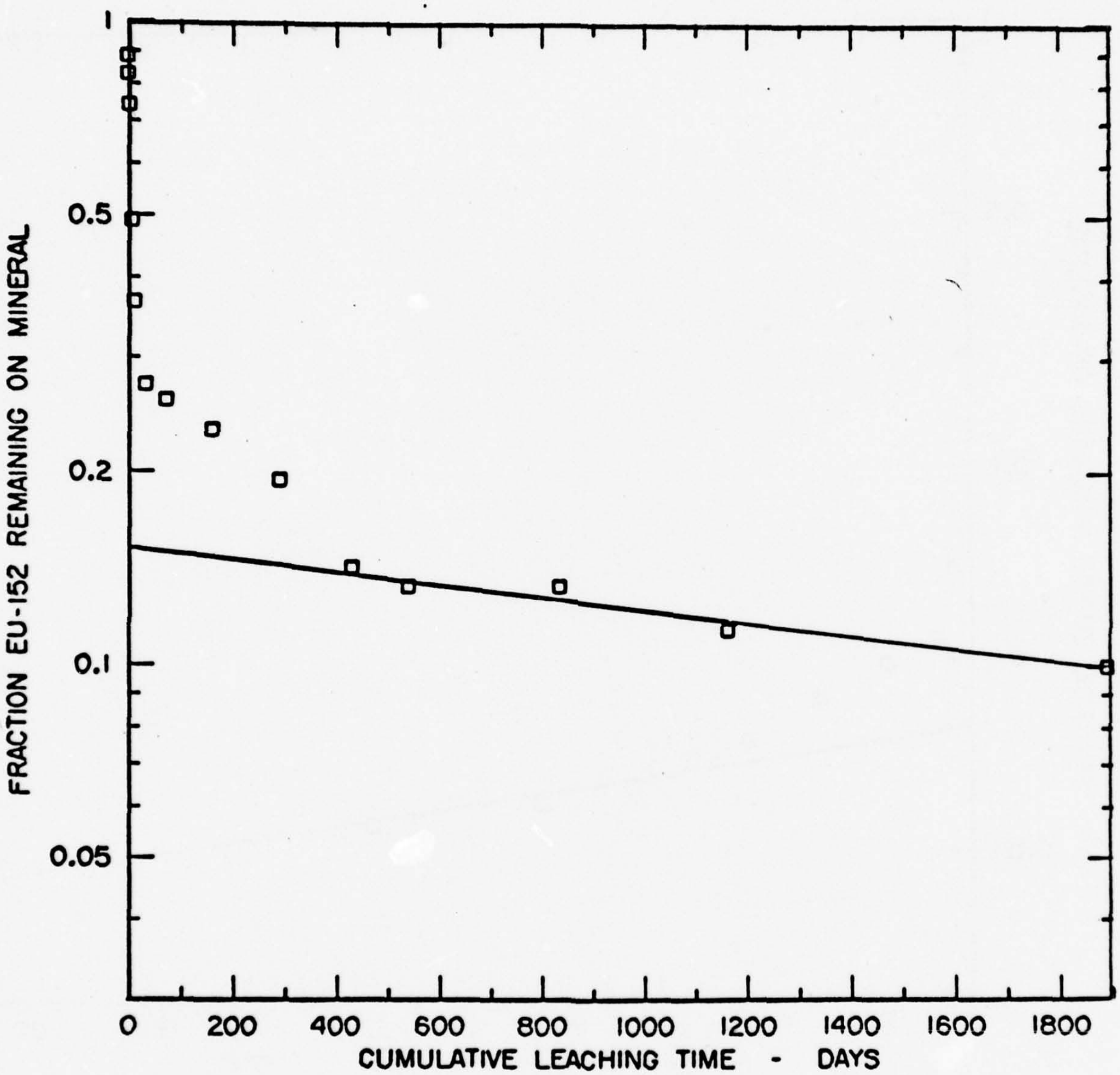

Figure 3. Leaching of Eu-152 from SMALL BOY Fallout.
Data obtained from Table 6.

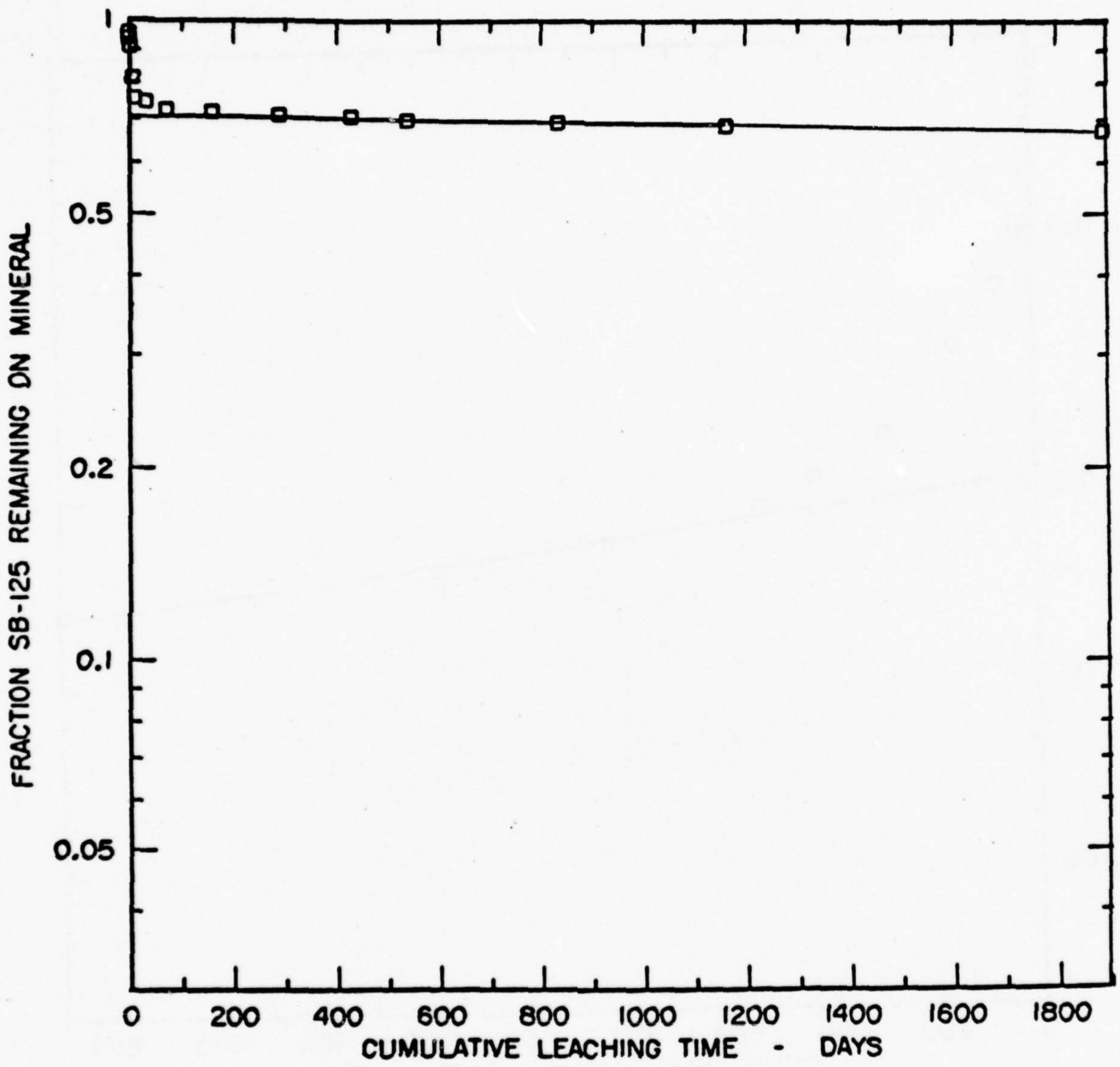

Figure 4. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 6.

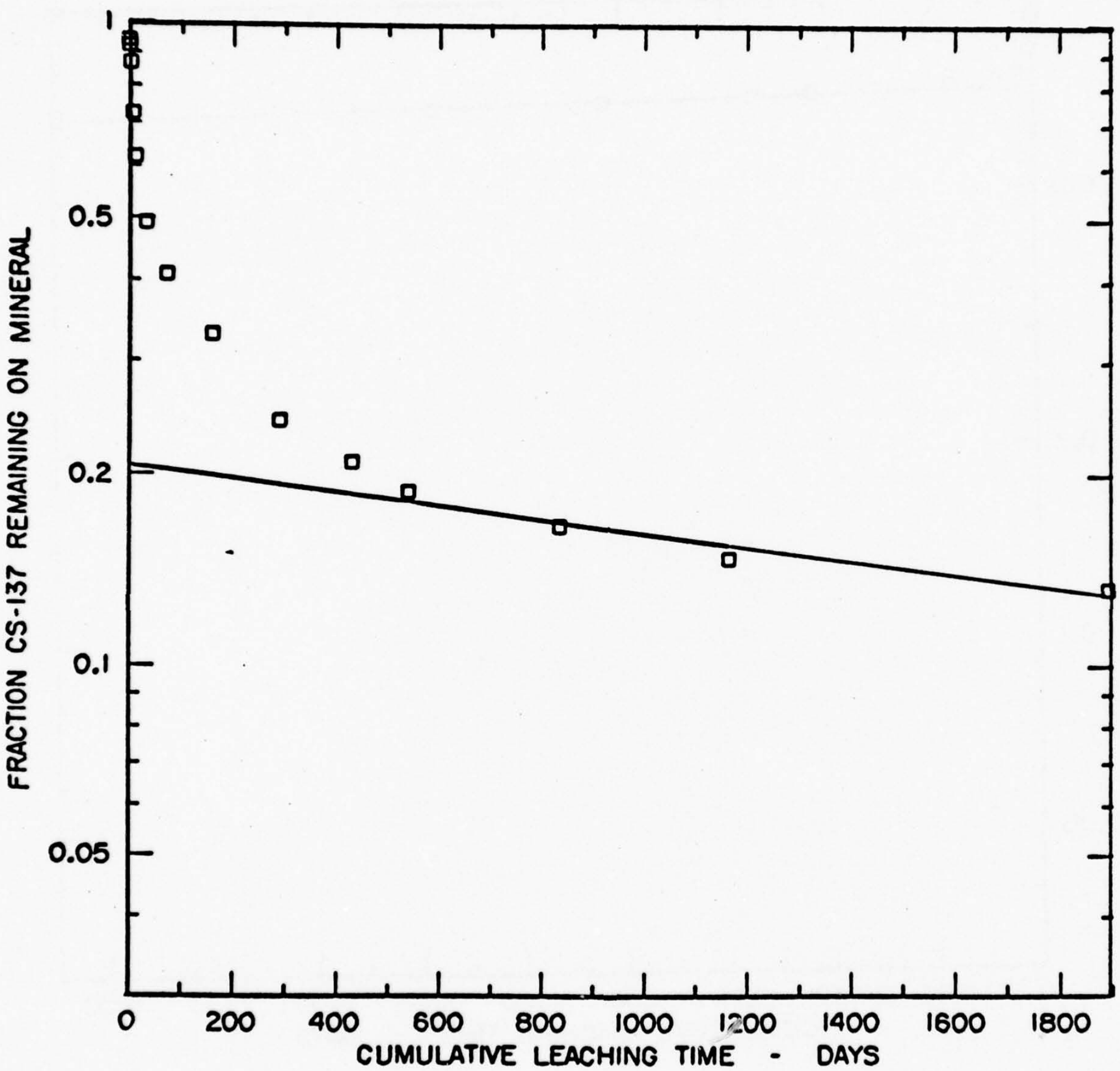

Figure 5. Leaching of Cs-137 from SMALL BOY Fallout.
Data obtained from Table 6.

Table 7

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL — STANDARD 40000.000 C/M
THERMAL TREATMENT 20 C — BACKGROUND .576 C/M
PARTICLE SIZE 710 - 350 MICRONS — LEACHING STARTED 11 NOV, 1969
COUNTING DATE 11 MAR. 1975

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.225 GM)			60.96	3059.26		
1 LEACH OF 20 ML	1	1	73.200	2736.48	3.6312	.8945
2 LEACH OF 20 ML	1	2	16.080	2667.58	.7752	.8720
3 LEACH OF 20 ML	1	3	47.100	2460.81	2.3262	.8044
4 LEACH OF 20 ML	6	9	157.320	1764.17	7.8372	.5767
5 LEACH OF 20 ML	4	13	82.800	1398.73	4.1112	.4572
6 LEACH OF 20 ML	21	34	136.560	794.36	6.7992	.2597
7 LEACH OF 20 ML	39	73	53.000	561.37	2.6212	.1835
8 LEACH OF 20 ML	87	160	17.640	485.53	.8532	.1587
9 LEACH OF 20 ML	130	290	15.960	417.16	.7692	.1364
10 LEACH OF 20 ML	140	430	9.840	375.99	.4632	.1229
11 LEACH OF 20 ML	110	540	4.140	360.15	.1782	.1177
12 LEACH OF 20 ML	294	834	8.100	326.71	.3762	.1068
13 LEACH OF 20 ML	330	1164	7.860	294.34	.3642	.0962
14 LEACH OF 20 ML	729	1893	6.420	268.37	.2922	.0877

BACKGROUND .110

CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.225 GM)			1.80	125.96		
1 LEACH OF 20 ML	1	1	6.300	98.44	.3095	.7816
2 LEACH OF 20 ML	1	2	1.260	93.33	.0575	.7410
3 LEACH OF 20 ML	1	3	2.880	81.02	.1385	.6433
4 LEACH OF 20 ML	6	9	5.460	57.24	.2675	.4545
5 LEACH OF 20 ML	4	13	3.600	41.73	.1745	.3313
6 LEACH OF 20 ML	21	34	2.100	32.89	.0995	.2611
7 LEACH OF 20 ML	39	73	2.760	21.11	.1325	.1676
8 LEACH OF 20 ML	87	160	.110	21.11	0.0000	.1676
9 LEACH OF 20 ML	130	290	.540	19.20	.0215	.1524
10 LEACH OF 20 ML	140	430	1.080	14.89	.0485	.1182
11 LEACH OF 20 ML	110	540	.360	13.78	.0125	.1094
12 LEACH OF 20 ML	294	834	.360	12.67	.0125	.1006
13 LEACH OF 20 ML	330	1164	1.020	8.62	.0455	.0685
14 LEACH OF 20 ML	729	1893	.360	7.51	.0125	.0596

Table 7 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 710 - 350 MICRONS
COUNTING DATE 11 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .050 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.225 GM)			37.44	224.93		
1 LEACH OF 20 ML	1	1	1.140	220.09	.0545	.9785
2 LEACH OF 20 ML	1	2	.360	218.71	.0155	.9723
3 LEACH OF 20 ML	1	3	1.140	213.87	.0545	.9508
4 LEACH OF 20 ML	6	9	4.140	195.69	.2045	.8700
5 LEACH OF 20 ML	4	13	.360	194.31	.0155	.8639
6 LEACH OF 20 ML	21	34	1.860	186.27	.0905	.8281
7 LEACH OF 20 ML	39	73	.540	184.09	.0245	.8184
8 LEACH OF 20 ML	87	160	.360	182.71	.0155	.8123
9 LEACH OF 20 ML	130	290	1.020	178.40	.0485	.7931
10 LEACH OF 20 ML	140	430	.360	177.02	.0155	.7870
11 LEACH OF 20 ML	110	540	.840	173.51	.0395	.7714
12 LEACH OF 20 ML	294	834	.240	172.67	.0095	.7676
13 LEACH OF 20 ML	330	1164	.840	169.16	.0395	.7520
14 LEACH OF 20 ML	729	1893	.720	166.18	.0335	.7388

BACKGROUND .887
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.225 GM)			68.04	1793.43		
1 LEACH OF 20 ML	1	1	21.060	1703.77	1.0087	.9500
2 LEACH OF 20 ML	1	2	8.940	1667.98	.4027	.9300
3 LEACH OF 20 ML	1	3	18.240	1590.85	.8677	.8870
4 LEACH OF 20 ML	6	9	67.020	1296.93	3.3067	.7232
5 LEACH OF 20 ML	4	13	41.100	1118.20	2.0107	.6235
6 LEACH OF 20 ML	21	34	64.440	835.74	3.1777	.4660
7 LEACH OF 20 ML	39	73	36.000	679.68	1.7557	.3790
8 LEACH OF 20 ML	87	160	25.320	571.09	1.2217	.3184
9 LEACH OF 20 ML	130	290	20.520	483.83	.9817	.2698
10 LEACH OF 20 ML	140	430	12.780	430.97	.5947	.2403
11 LEACH OF 20 ML	110	540	6.900	404.24	.3007	.2254
12 LEACH OF 20 ML	294	834	8.700	369.51	.3907	.2060
13 LEACH OF 20 ML	330	1164	9.660	330.52	.4387	.1843
14 LEACH OF 20 ML	729	1893	8.100	298.46	.3607	.1664

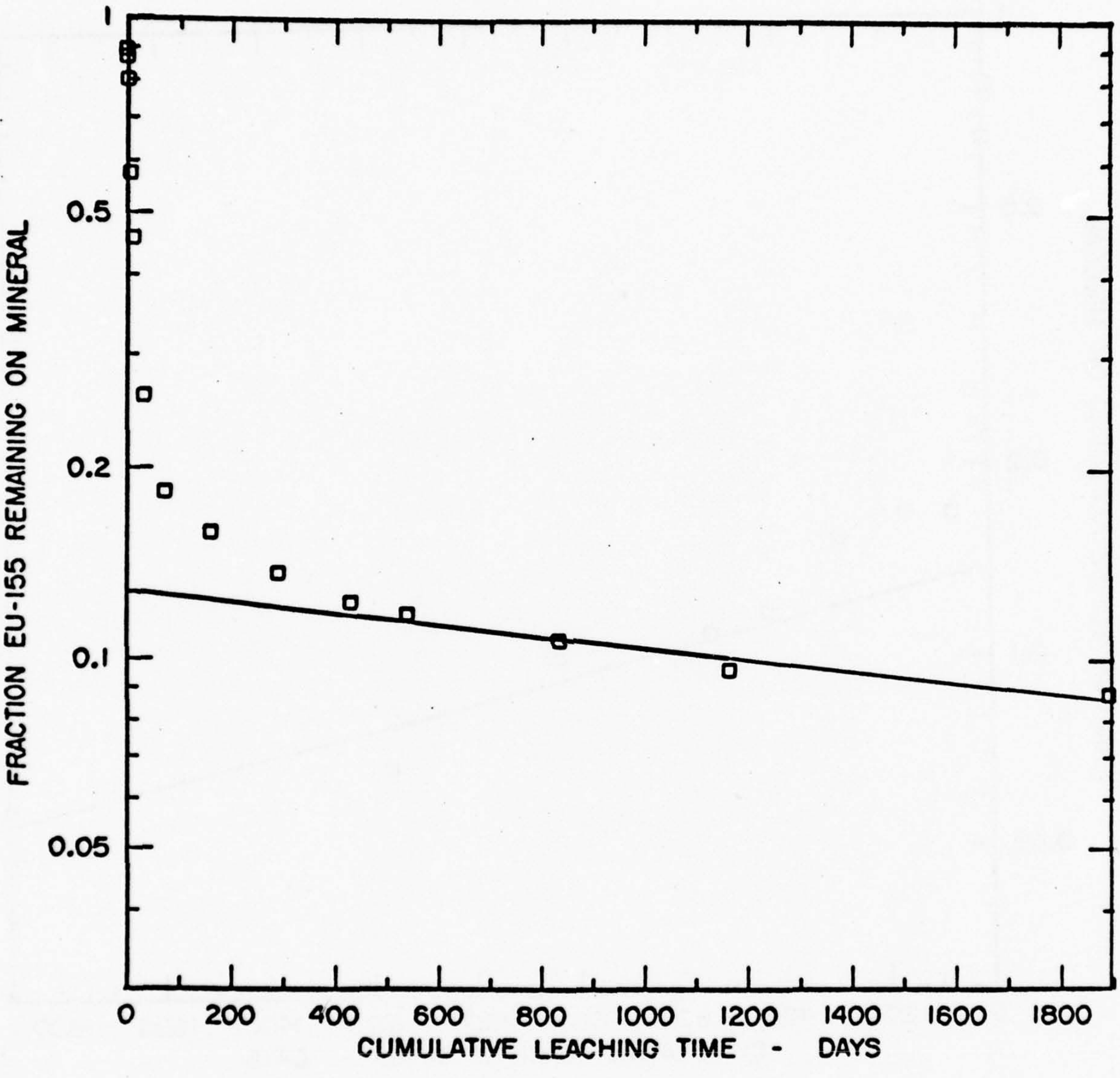

Figure 6. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 7.

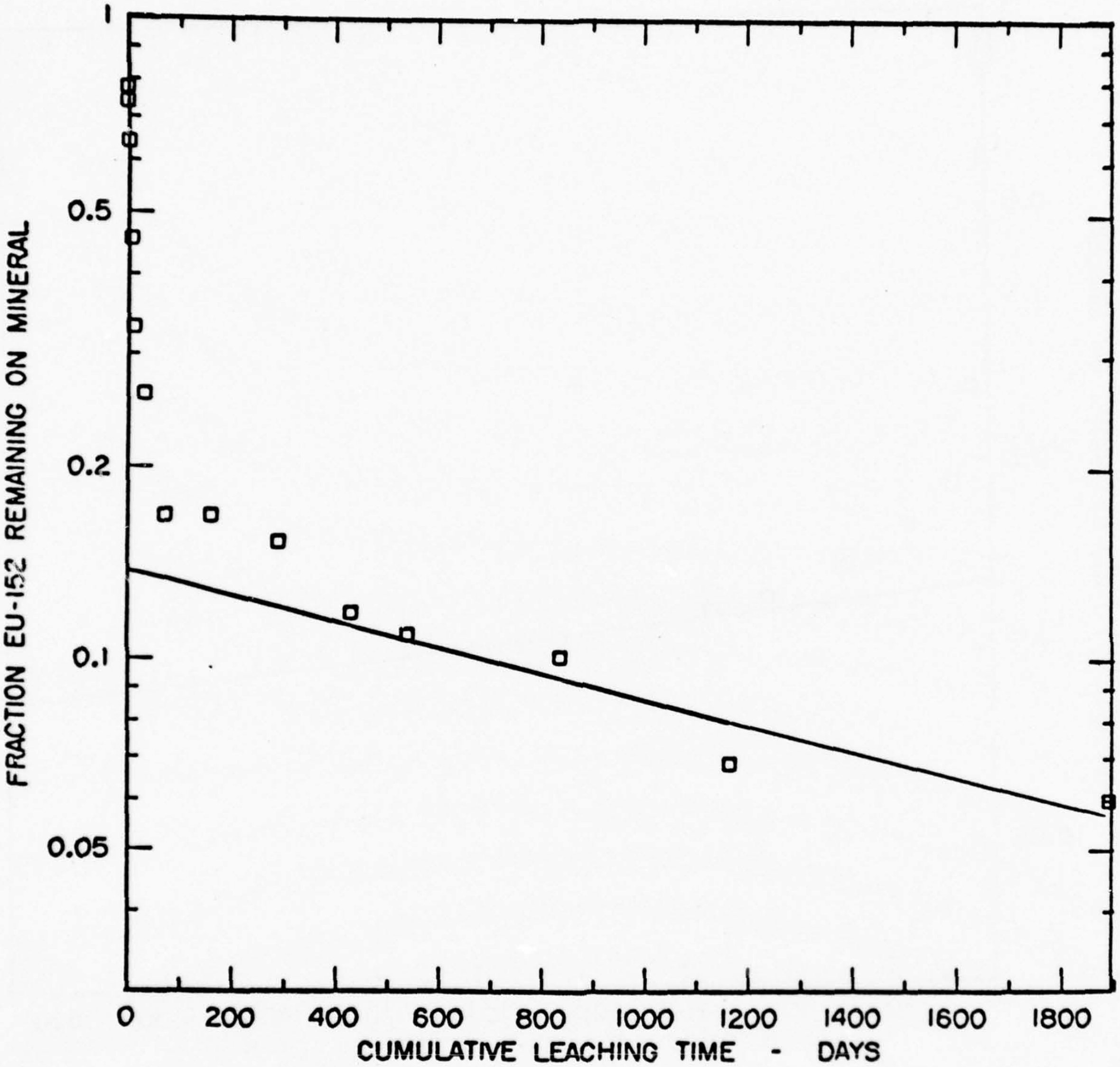

Figure 7. Leaching of Eu-152 from SMALL BOY Fallout. Data obtained from Table 7.

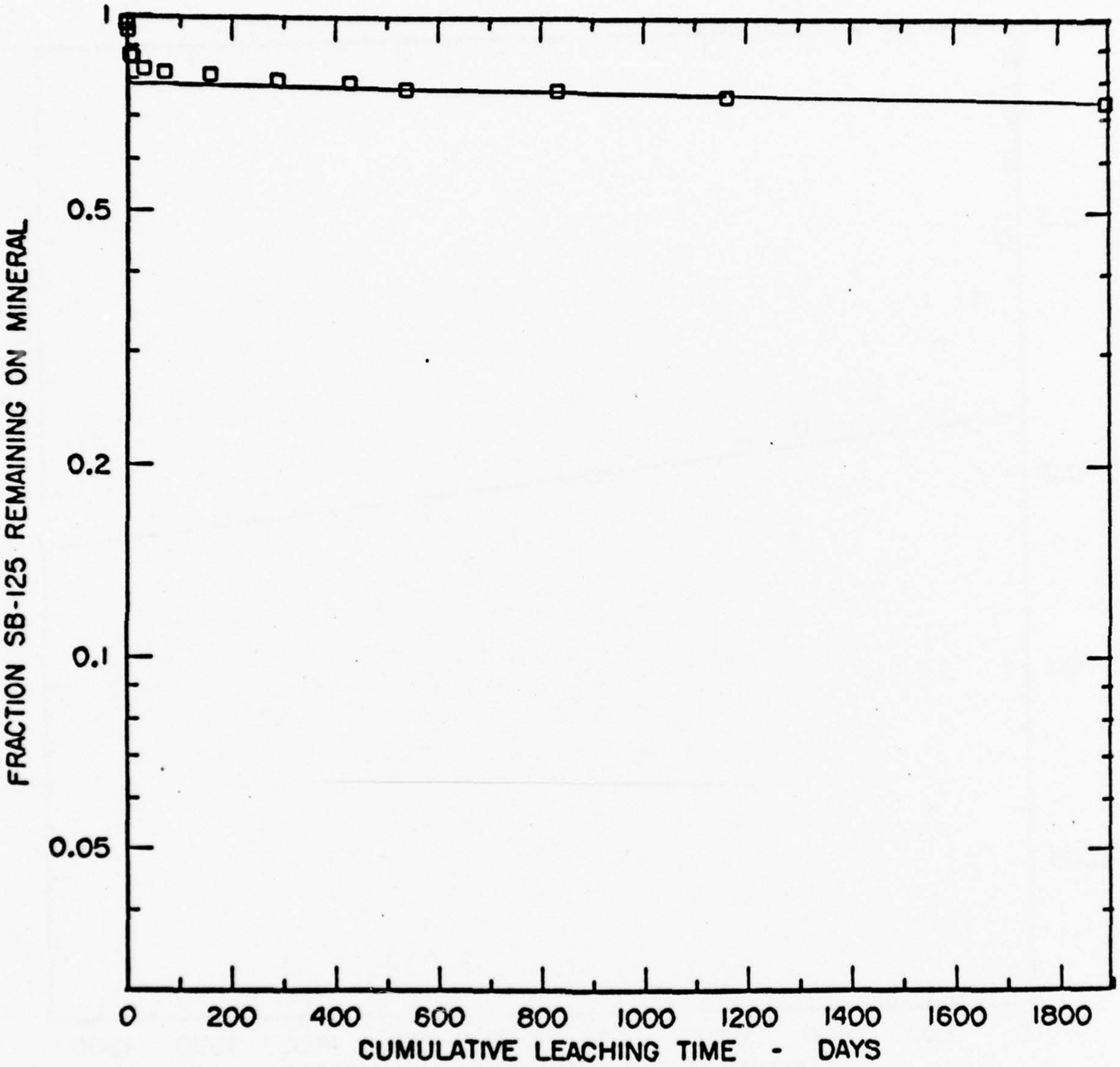

Figure 8. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 7.

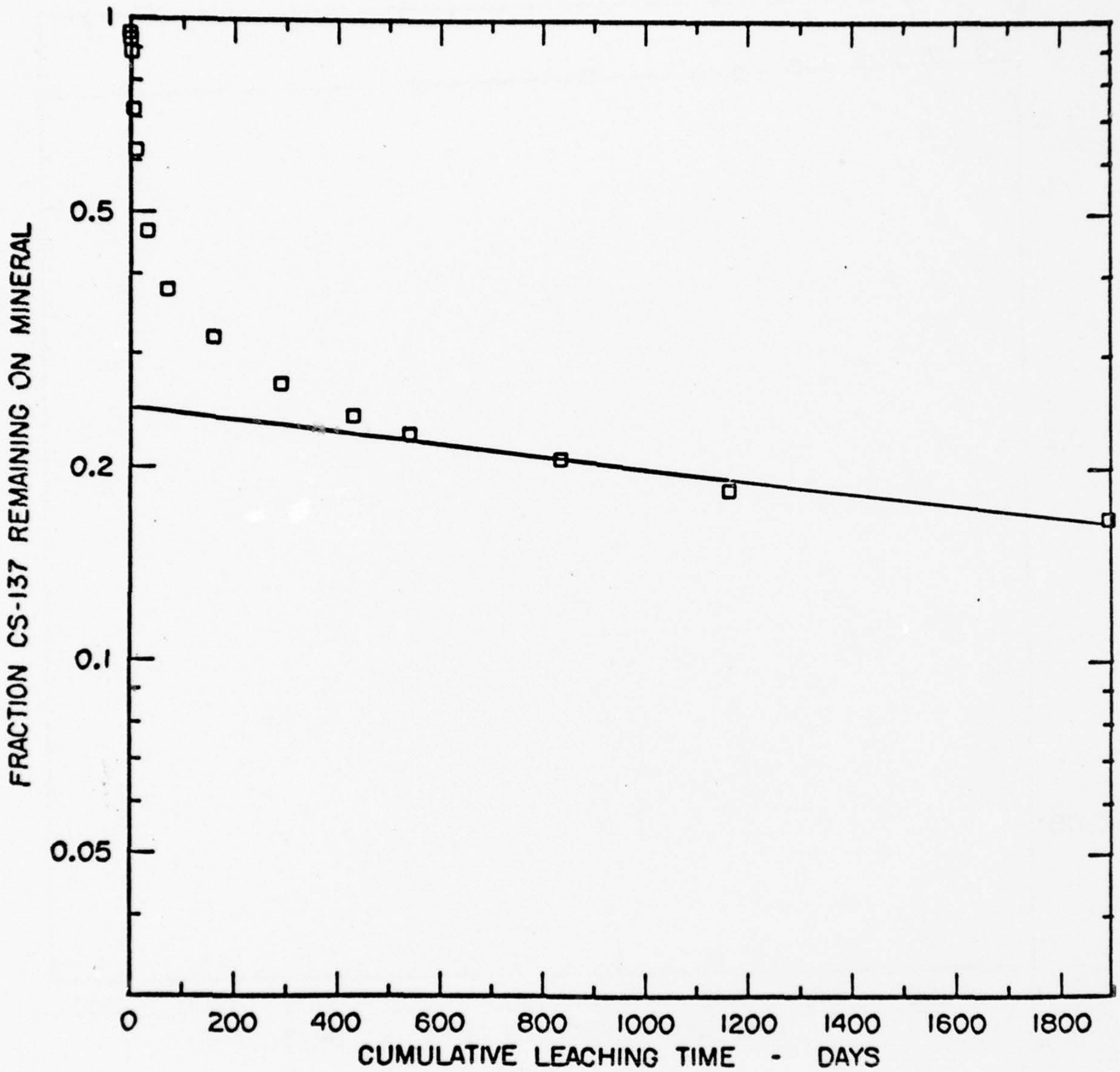

Figure 9. Leaching of Cs-137 from SMALL BOY Fallout.
Data obtained from Table 7.

Table 8

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 177 - 88 MICRONS
COUNTING DATE 13 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .540 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.177 GM)			3.06	229.15		
1 LEACH OF 20 ML	1	1	8.040	186.78	.3750	.8151
2 LEACH OF 20 ML	1	2	2.160	177.63	.0810	.7751
3 LEACH OF 20 ML	1	3	6.720	142.71	.3090	.6228
4 LEACH OF 20 ML	6	9	5.640	113.90	.2550	.4970
5 LEACH OF 20 ML	4	13	2.100	105.08	.0780	.4586
6 LEACH OF 20 ML	21	34	.900	103.05	.0180	.4497
7 LEACH OF 20 ML	39	73	2.580	91.53	.1020	.3994
8 LEACH OF 20 ML	87	160	1.020	88.81	.0240	.3876
9 LEACH OF 20 ML	130	290	3.720	70.85	.1590	.3092
10 LEACH OF 20 ML	140	430	3.240	55.59	.1350	.2426
11 LEACH OF 20 ML	110	540	.540	55.59	0.0000	.2426
12 LEACH OF 20 ML	294	834	3.240	40.34	.1350	.1760
13 LEACH OF 20 ML	330	1164	3.480	23.73	.1470	.1036
14 LEACH OF 20 ML	729	1893	2.220	14.24	.0840	.0621

BACKGROUND .090
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.177 GM)			1.14	35.59		
1 LEACH OF 20 ML	1	1	.480	33.39	.0195	.9381
2 LEACH OF 20 ML	1	2	.240	32.54	.0075	.9143
3 LEACH OF 20 ML	1	3	.090	32.54	0.0000	.9143
4 LEACH OF 20 ML	6	9	.840	28.31	.0375	.7952
5 LEACH OF 20 ML	4	13	.540	25.76	.0225	.7238
6 LEACH OF 20 ML	21	34	.960	20.85	.0435	.5857
7 LEACH OF 20 ML	39	73	.420	18.98	.0165	.5333
8 LEACH OF 20 ML	87	160	.960	14.07	.0435	.3952
9 LEACH OF 20 ML	130	290	.780	10.17	.0345	.2857
10 LEACH OF 20 ML	140	430	.090	10.17	0.0000	.2857
11 LEACH OF 20 ML	110	540	.840	5.93	.0375	.1667
12 LEACH OF 20 ML	294	834	.090	5.93	0.0000	.1667
13 LEACH OF 20 ML	330	1164	.090	5.93	0.0000	.1667
14 LEACH OF 20 ML	729	1893	.090	5.93	0.0000	.1667

Table 8 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 177 - 88 MICRONS
COUNTING DATE 13 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .360 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.177 GM)			2.52	24.80		
1 LEACH OF 20 ML	1	1	.360	24.80	0.0000	1.0000
2 LEACH OF 20 ML	1	2	.360	24.80	0.0000	1.0000
3 LEACH OF 20 ML	1	3	.360	24.80	0.0000	1.0000
4 LEACH OF 20 ML	6	9	.360	24.80	0.0000	1.0000
5 LEACH OF 20 ML	4	13	.660	23.11	.0150	.9317
6 LEACH OF 20 ML	21	34	.360	23.11	0.0000	.9317
7 LEACH OF 20 ML	39	73	.720	21.07	.0180	.8497
8 LEACH OF 20 ML	87	160	.730	18.98	.0185	.7654
9 LEACH OF 20 ML	130	290	.720	16.95	.0180	.6834
10 LEACH OF 20 ML	140	430	.360	16.95	0.0000	.6834
11 LEACH OF 20 ML	110	540	.600	15.59	.0120	.6287
12 LEACH OF 20 ML	294	834	.480	14.92	.0060	.6014
13 LEACH OF 20 ML	330	1164	.840	12.20	.0240	.4920
14 LEACH OF 20 ML	729	1893	.360	12.20	0.0000	.4920

BACKGROUND .270
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.177 GM)			5.22	116.27		
1 LEACH OF 20 ML	1	1	.840	113.05	.0285	.9723
2 LEACH OF 20 ML	1	2	1.680	105.08	.0705	.9038
3 LEACH OF 20 ML	1	3	.780	102.20	.0255	.8790
4 LEACH OF 20 ML	6	9	1.440	95.59	.0585	.8222
5 LEACH OF 20 ML	4	13	.480	94.41	.0105	.8120
6 LEACH OF 20 ML	21	34	1.260	88.81	.0495	.7638
7 LEACH OF 20 ML	39	73	.720	86.27	.0225	.7420
8 LEACH OF 20 ML	87	160	1.620	78.64	.0675	.6764
9 LEACH OF 20 ML	130	290	2.580	65.59	.1155	.5641
10 LEACH OF 20 ML	140	430	1.980	55.93	.0855	.4810
11 LEACH OF 20 ML	110	540	.270	55.93	0.0000	.4810
12 LEACH OF 20 ML	294	834	1.140	51.02	.0435	.4388
13 LEACH OF 20 ML	330	1164	2.160	40.34	.0945	.3469
14 LEACH OF 20 ML	729	1893	2.460	27.97	.1095	.2405

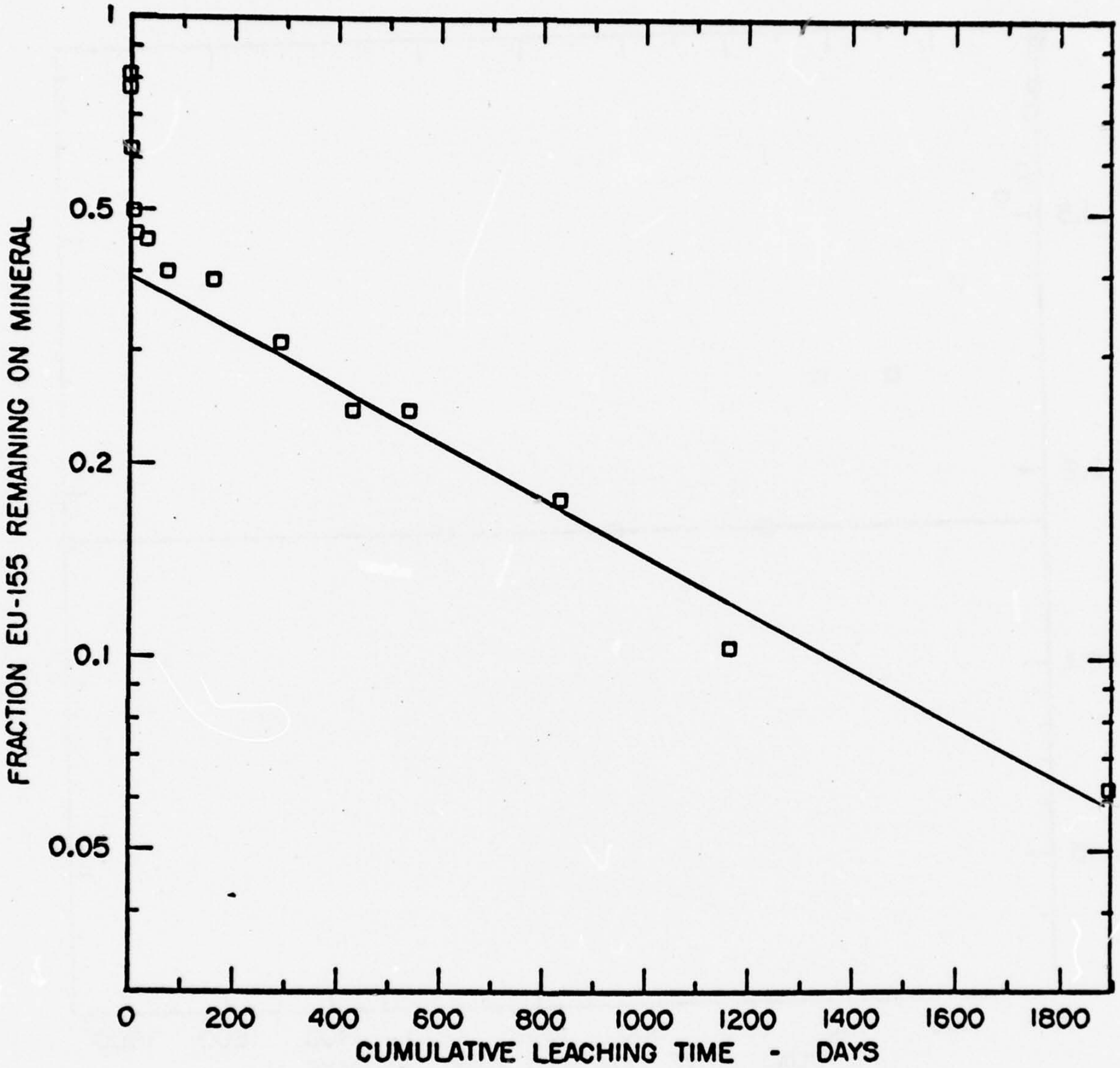

Figure 10. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 8.

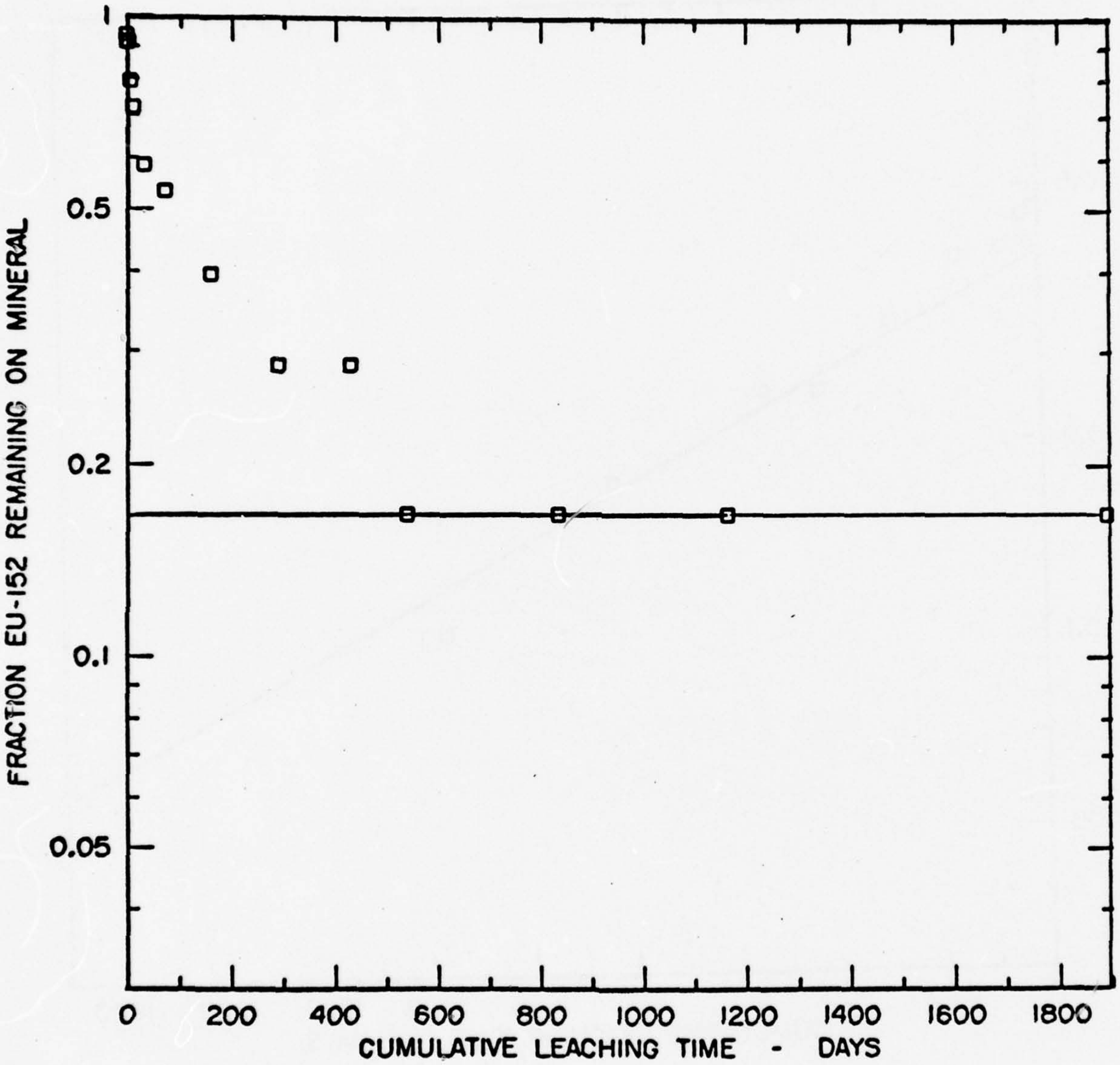

Figure 11. Leaching of Eu-152 from SMALL BOY Fallout. Data obtained from Table 8.

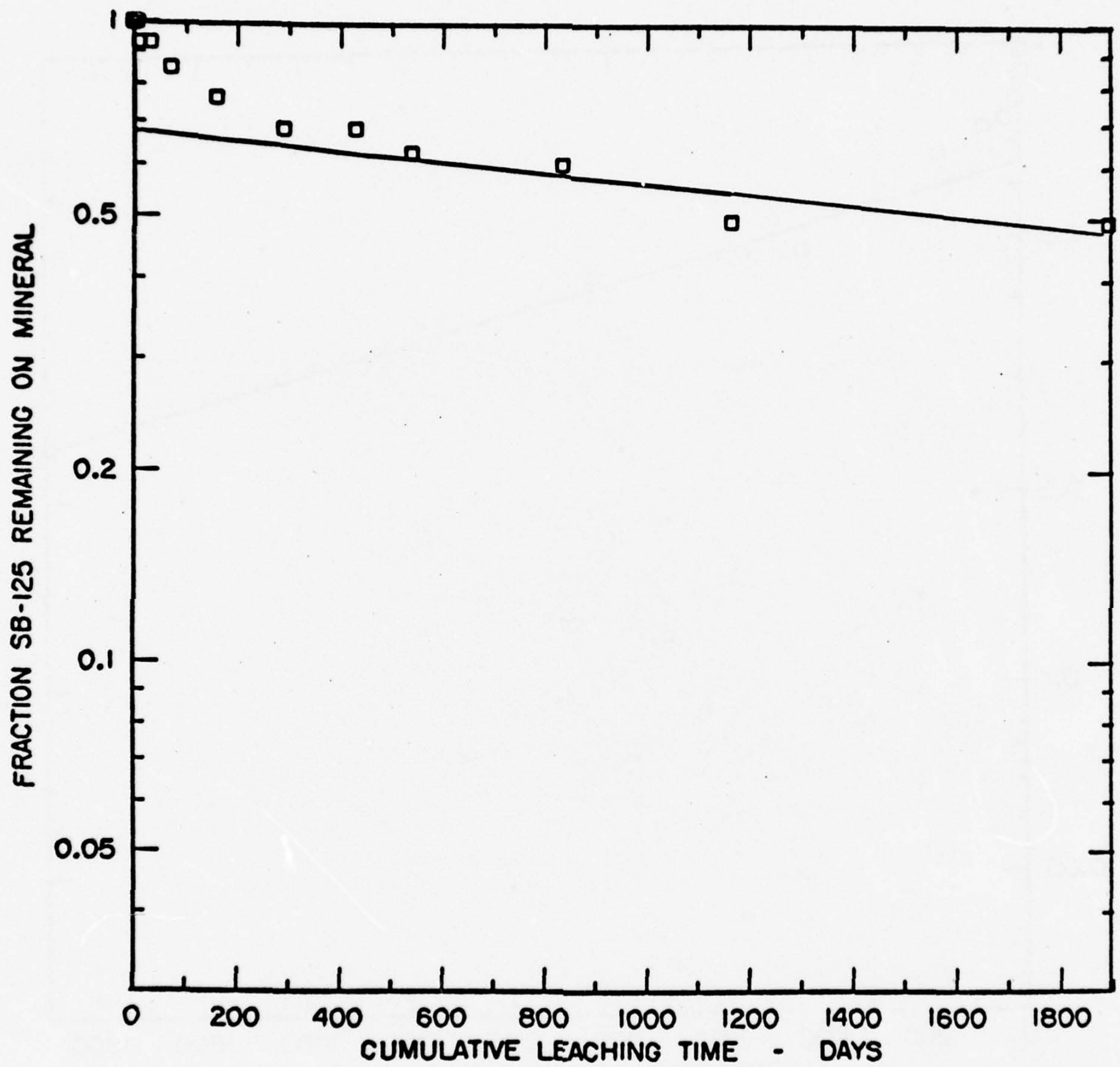

Figure 12. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 8.

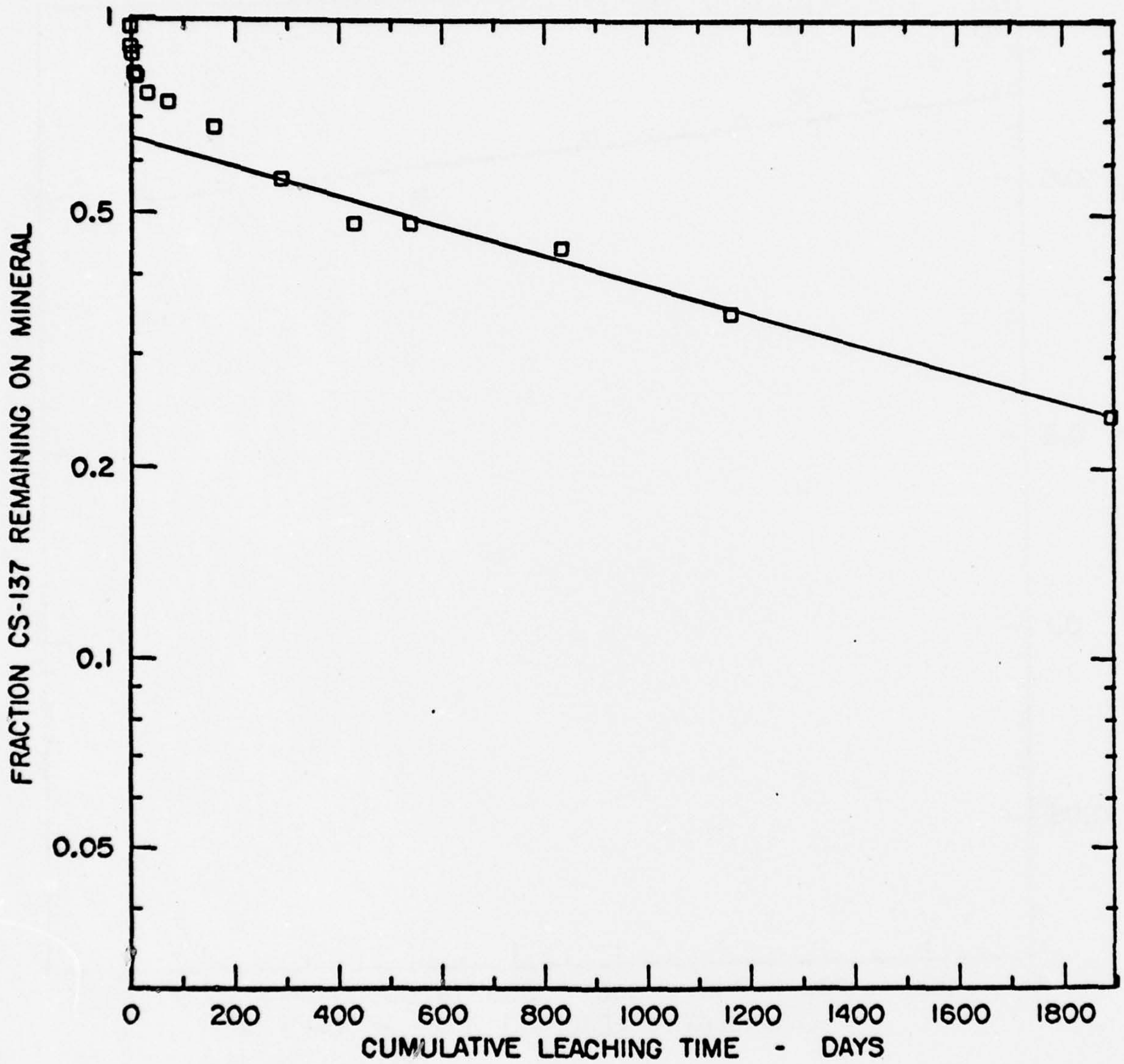

Figure 13. Leaching of Cs-137 from SMALL BOY Fallout.
Data obtained from Table 8.

Table 9

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 44 - 0 MICRONS
COUNTING DATE 16 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND 1.660 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.338 GM)			4.68	64.73		
1 LEACH OF 20 ML	1	1	2.100	63.43	.0220	.9799
2 LEACH OF 20 ML	1	2	1.660	63.43	0.0000	.9799
3 LEACH OF 20 ML	1	3	4.560	54.85	.1450	.8473
4 LEACH OF 20 ML	6	9	1.660	54.85	0.0000	.8473
5 LEACH OF 20 ML	4	13	1.660	54.85	0.0000	.8473
6 LEACH OF 20 ML	21	34	2.100	53.55	.0220	.8272
7 LEACH OF 20 ML	39	73	2.820	50.12	.0580	.7742
8 LEACH OF 20 ML	87	160	3.780	43.85	.1060	.6773
9 LEACH OF 20 ML	130	290	4.140	36.51	.1240	.5640
10 LEACH OF 20 ML	140	430	1.980	35.56	.0160	.5494
11 LEACH OF 20 ML	110	540	7.020	19.70	.2680	.3044
12 LEACH OF 20 ML	294	834	4.380	11.66	.1360	.1801
13 LEACH OF 20 ML	330	1164	2.580	8.93	.0460	.1380
14 LEACH OF 20 ML	729	1893	1.660	8.93	0.0000	.1380

BACKGROUND .280
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.338 GM)			.90	13.49		
1 LEACH OF 20 ML	1	1	.900	11.66	.0310	.8640
2 LEACH OF 20 ML	1	2	.900	9.82	.0310	.7281
3 LEACH OF 20 ML	1	3	.360	9.59	.0040	.7105
4 LEACH OF 20 ML	6	9	.280	9.59	0.0000	.7105
5 LEACH OF 20 ML	4	13	.780	8.11	.0250	.6009
6 LEACH OF 20 ML	21	34	.540	7.34	.0130	.5439
7 LEACH OF 20 ML	39	73	.420	6.92	.0070	.5132
8 LEACH OF 20 ML	87	160	.280	6.92	0.0000	.5132
9 LEACH OF 20 ML	130	290	.780	5.44	.0250	.4035
10 LEACH OF 20 ML	140	430	.280	5.44	0.0000	.4035
11 LEACH OF 20 ML	110	540	.600	4.50	.0160	.3333
12 LEACH OF 20 ML	294	834	.360	4.26	.0040	.3158
13 LEACH OF 20 ML	330	1164	1.080	1.89	.0400	.1404
14 LEACH OF 20 ML	729	1893	.300	1.83	.0010	.1360

Table 9 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 44 - 0 MICRONS
COUNTING DATE 16 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .280 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.338 GM)			2.04	13.14		
1 LEACH OF 20 ML	1	1	.300	13.08	.0010	.9955
2 LEACH OF 20 ML	1	2	.280	13.08	0.0000	.9955
3 LEACH OF 20 ML	1	3	.280	13.08	0.0000	.9955
4 LEACH OF 20 ML	6	9	.840	11.42	.0280	.8694
5 LEACH OF 20 ML	4	13	.280	11.42	0.0000	.8694
6 LEACH OF 20 ML	21	34	.600	10.47	.0160	.7973
7 LEACH OF 20 ML	39	73	.280	10.47	0.0000	.7973
8 LEACH OF 20 ML	87	160	.720	9.17	.0220	.6982
9 LEACH OF 20 ML	130	290	.960	7.16	.0340	.5450
10 LEACH OF 20 ML	140	430	.280	7.16	0.0000	.5450
11 LEACH OF 20 ML	110	540	.420	6.75	.0070	.5135
12 LEACH OF 20 ML	294	834	.540	5.98	.0130	.4550
13 LEACH OF 20 ML	330	1164	.280	5.98	0.0000	.4550
14 LEACH OF 20 ML	729	1893	.540	5.21	.0130	.3964

BACKGROUND .840
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.338 GM)			8.46	44.73		
1 LEACH OF 20 ML	1	1	1.200	43.67	.0180	.9762
2 LEACH OF 20 ML	1	2	.960	43.31	.0060	.9683
3 LEACH OF 20 ML	1	3	.840	43.31	0.0000	.9683
4 LEACH OF 20 ML	6	9	.840	43.31	0.0000	.9683
5 LEACH OF 20 ML	4	13	.840	43.31	0.0000	.9683
6 LEACH OF 20 ML	21	34	1.140	42.43	.0150	.9484
7 LEACH OF 20 ML	39	73	.900	42.25	.0030	.9444
8 LEACH OF 20 ML	87	160	1.320	40.83	.0240	.9127
9 LEACH OF 20 ML	130	290	2.100	37.10	.0630	.8294
10 LEACH OF 20 ML	140	430	1.620	34.79	.0390	.7778
11 LEACH OF 20 ML	110	540	1.800	31.95	.0480	.7143
12 LEACH OF 20 ML	294	834	1.740	29.29	.0450	.6548
13 LEACH OF 20 ML	330	1164	2.520	24.32	.0840	.5437
14 LEACH OF 20 ML	729	1893	1.440	22.54	.0300	.5040

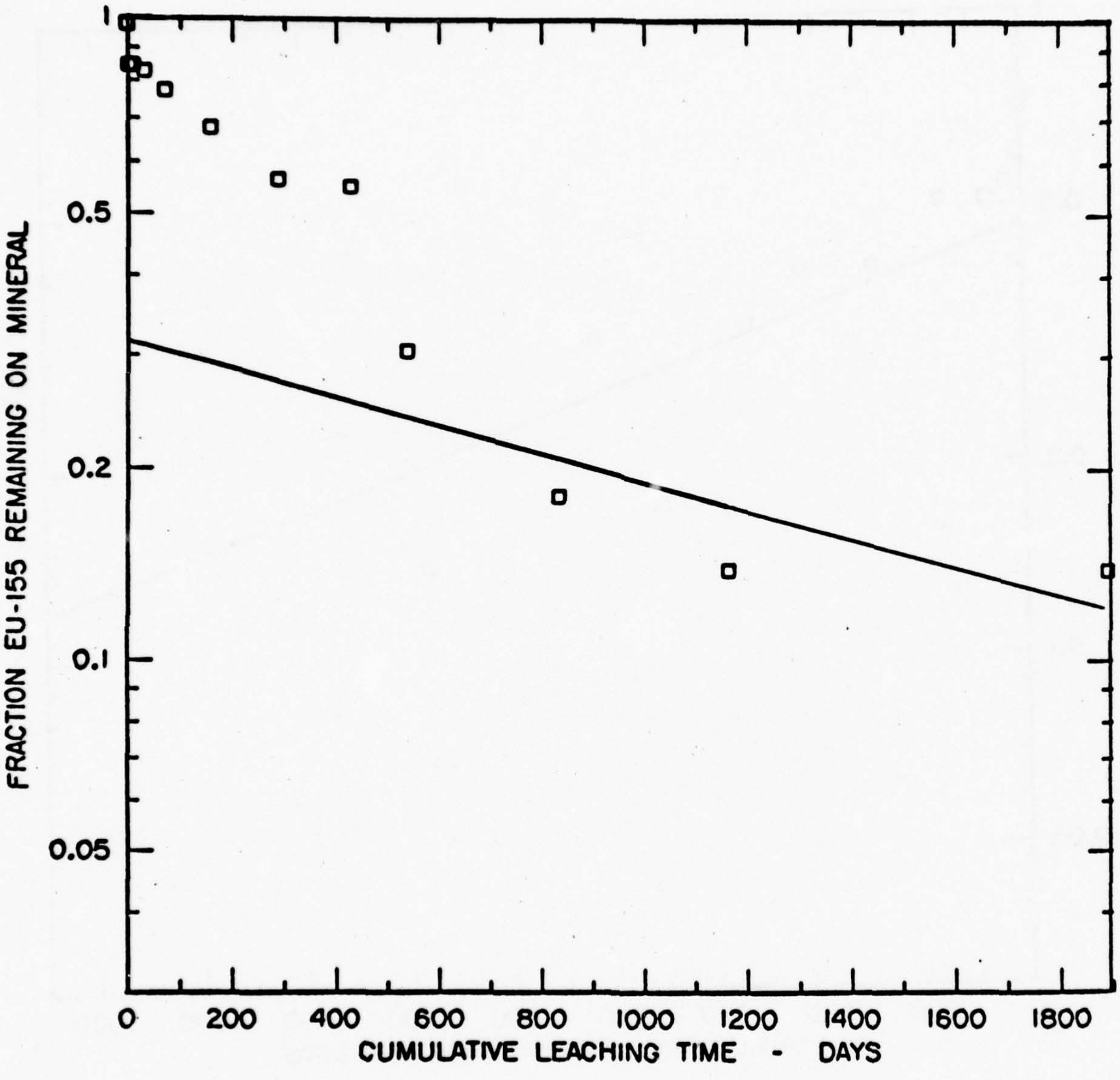

Figure 14. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 9.

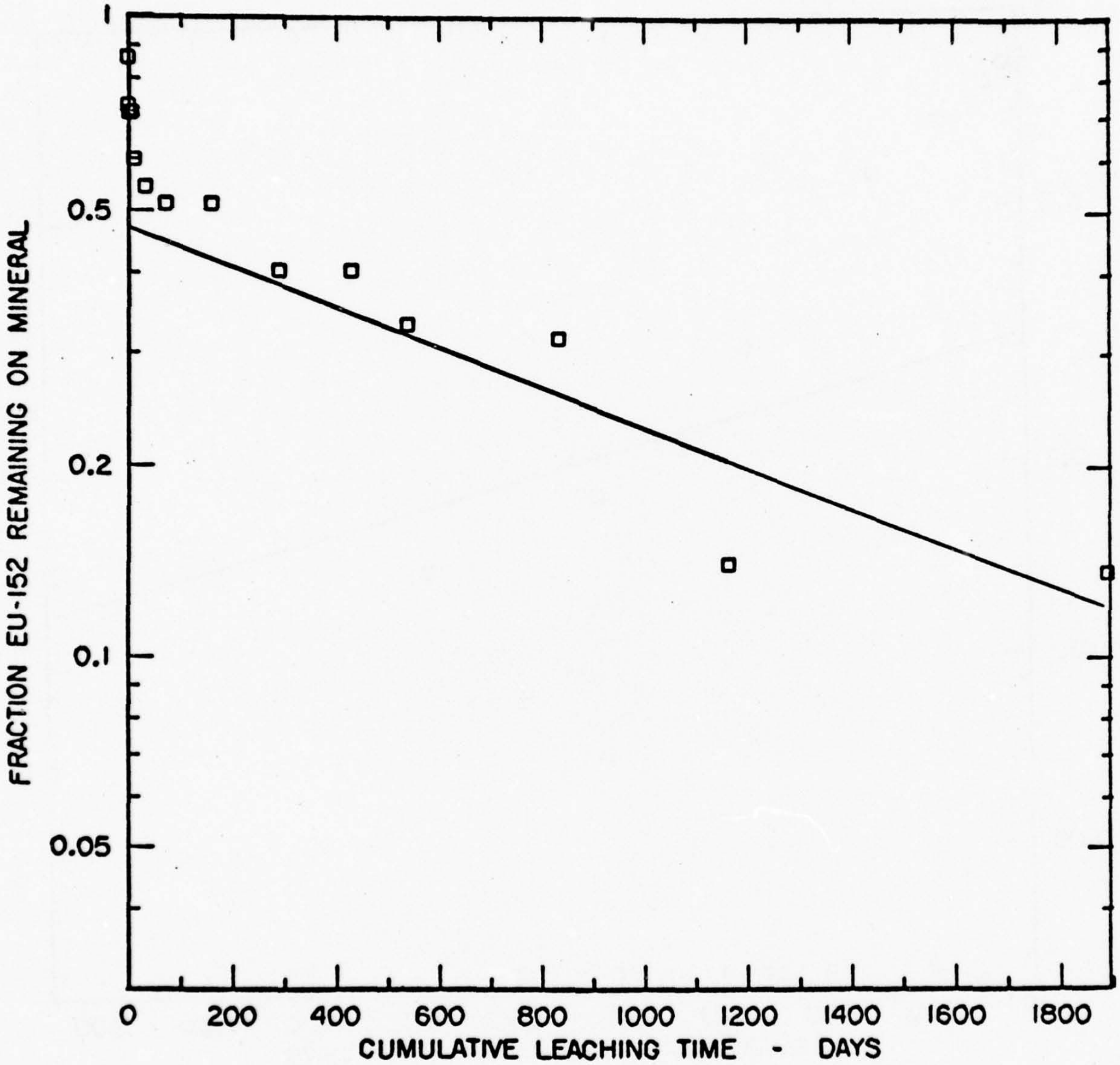

Figure 15. Leaching of Eu-152 from SMALL BOY Fallout. Data obtained from Table 9.

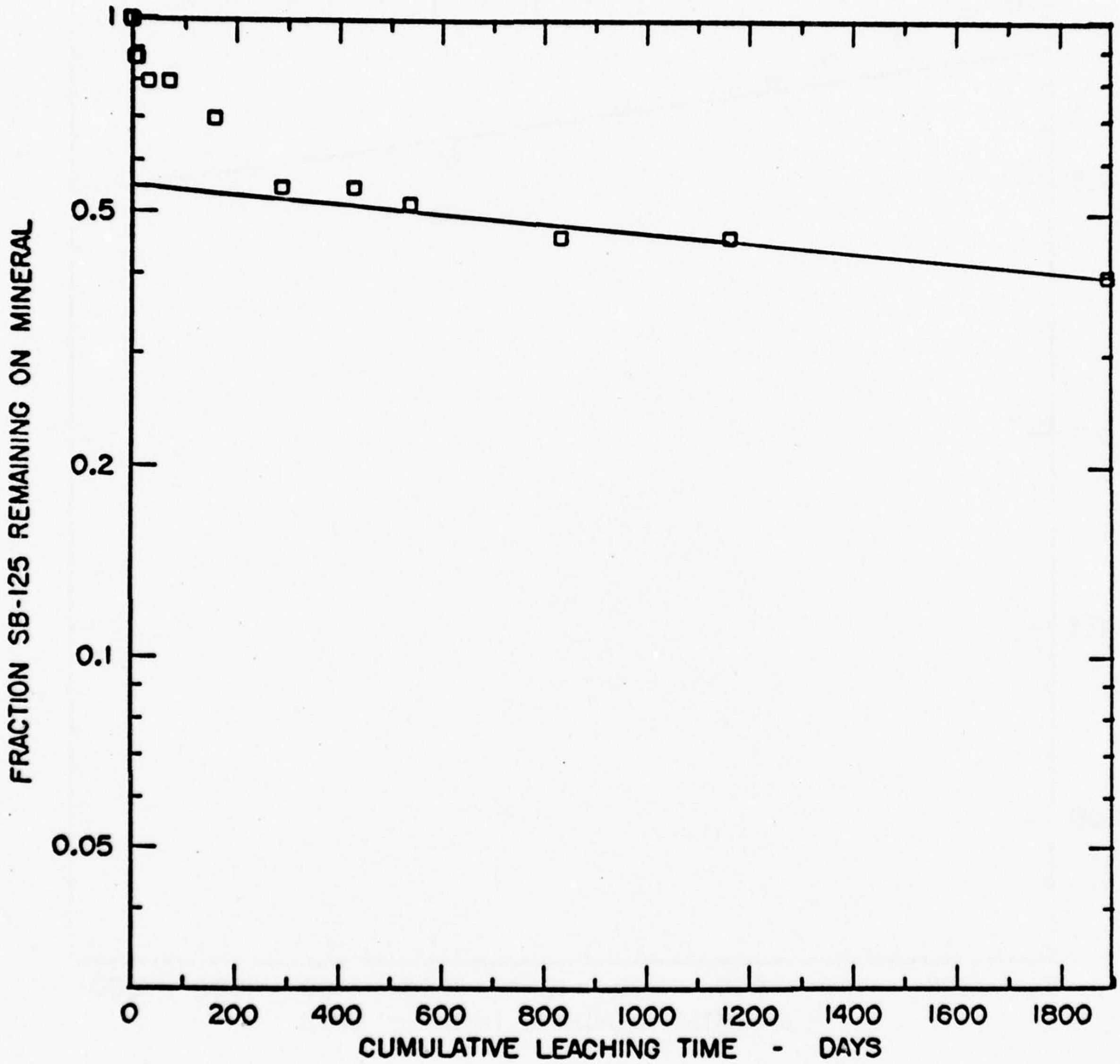

Figure 16. Leaching of Sb-125 from SMALL BOY Fallout.
Data obtained from Table 9.

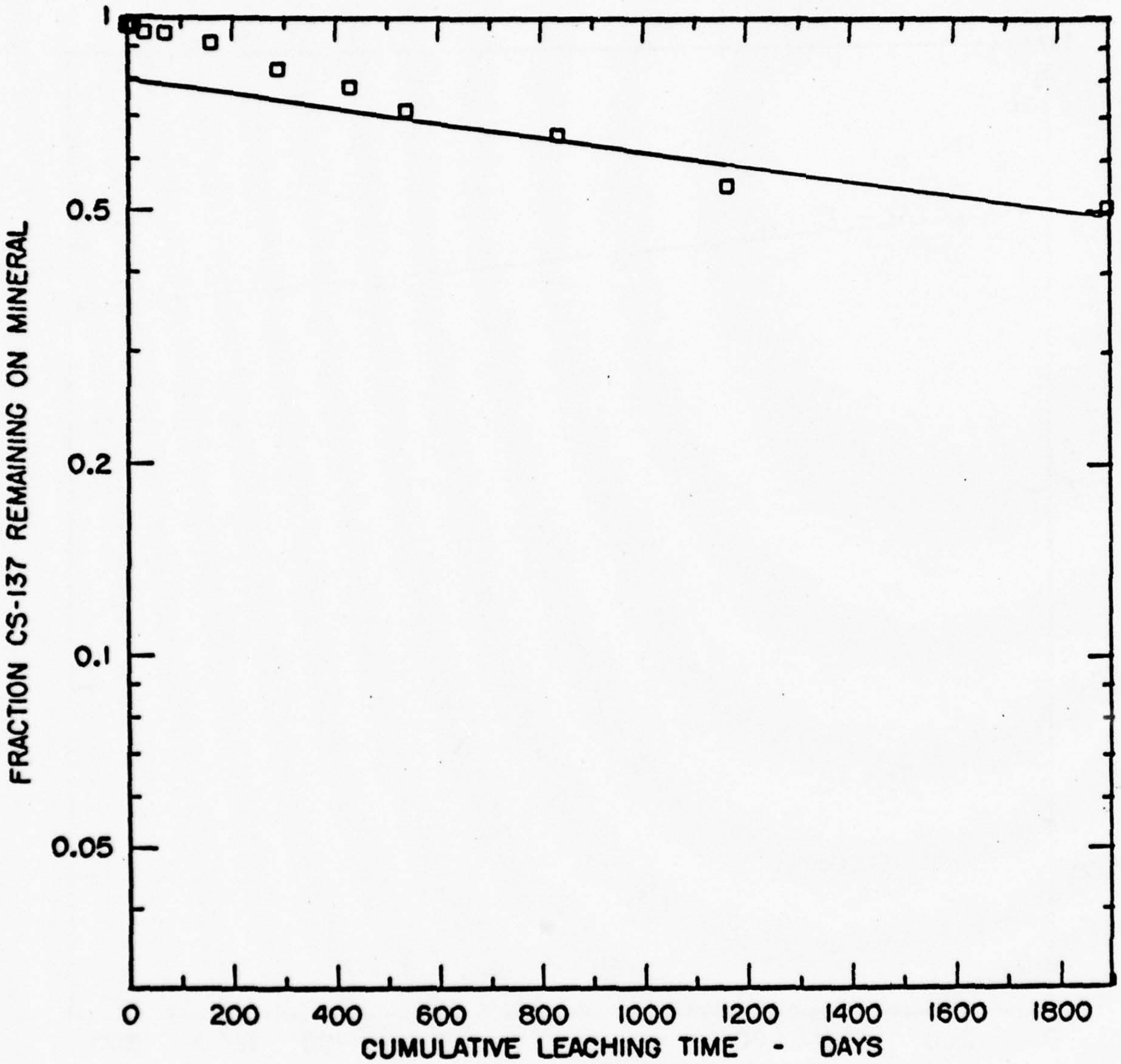

Figure 17. Leaching of Cs-137 from SMALL BOY Fallout.
Data obtained from Table 9.

Table 10

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH
THERMAL TREATMENT 20 C
PARTICLE SIZE 1410 - 710 MICRONS
COUNTING DATE 20 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND 1.480 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.345 GM)			103.56	2264.23		
1 LEACH OF 20 ML	1	1	1.560	2264.00	.0040	.9999
2 LEACH OF 20 ML	1	2	2.040	2262.38	.0280	.9992
3 LEACH OF 20 ML	1	3	2.400	2259.71	.0460	.9980
4 LEACH OF 20 ML	6	9	1.480	2259.71	0.0000	.9980
5 LEACH OF 20 ML	4	13	1.480	2259.71	0.0000	.9980
6 LEACH OF 20 ML	21	34	2.820	2255.83	.0670	.9963
7 LEACH OF 20 ML	39	73	4.620	2246.72	.1570	.9923
8 LEACH OF 20 ML	87	160	236.340	1565.97	11.7430	.6916
9 LEACH OF 20 ML	130	290	285.060	744.00	14.1790	.3286
10 LEACH OF 20 ML	140	430	75.600	529.16	3.7060	.2337
11 LEACH OF 20 ML	110	540	25.860	458.49	1.2190	.2025
12 LEACH OF 20 ML	294	834	23.760	393.91	1.1140	.1740
13 LEACH OF 20 ML	330	1164	13.920	357.86	.6220	.1580
14 LEACH OF 20 ML	729	1893	22.860	295.88	1.0690	.1307

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .331
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.345 GM)			5.76	109.00		
1 LEACH OF 20 ML	1	1	.720	107.88	.0194	.9897
2 LEACH OF 20 ML	1	2	.480	107.44	.0075	.9857
3 LEACH OF 20 ML	1	3	1.500	104.06	.0584	.9546
4 LEACH OF 20 ML	6	9	.900	102.41	.0284	.9395
5 LEACH OF 20 ML	4	13	.331	102.41	0.0000	.9395
6 LEACH OF 20 ML	21	34	.540	101.80	.0104	.9339
7 LEACH OF 20 ML	39	73	.840	100.32	.0254	.9204
8 LEACH OF 20 ML	87	160	11.640	67.54	.5654	.6197
9 LEACH OF 20 ML	130	290	13.800	28.50	.6734	.2615
10 LEACH OF 20 ML	140	430	1.800	24.25	.0734	.2224
11 LEACH OF 20 ML	110	540	.720	23.12	.0194	.2121
12 LEACH OF 20 ML	294	834	1.500	19.73	.0584	.1810
13 LEACH OF 20 ML	330	1164	.840	18.26	.0254	.1675
14 LEACH OF 20 ML	729	1893	1.200	15.74	.0434	.1444

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

Table 10 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH
THERMAL TREATMENT 20 C
PARTICLE SIZE 1410 - 710 MICRONS
COUNTING DATE 20 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .270 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.345 GM)			49.38	180.26		
1 LEACH OF 20 ML	1	1	.270	180.26	0.0000	1.0000
2 LEACH OF 20 ML	1	2	.660	179.13	.0195	.9937
3 LEACH OF 20 ML	1	3	.900	177.30	.0315	.9836
4 LEACH OF 20 ML	6	9	.420	176.87	.0075	.9812
5 LEACH OF 20 ML	4	13	.900	175.04	.0315	.9711
6 LEACH OF 20 ML	21	34	.660	173.91	.0195	.9648
7 LEACH OF 20 ML	39	73	.720	172.61	.0225	.9575
8 LEACH OF 20 ML	87	160	6.240	155.30	.2985	.8616
9 LEACH OF 20 ML	130	290	3.420	146.17	.1575	.8109
10 LEACH OF 20 ML	140	430	.600	145.22	.0165	.8056
11 LEACH OF 20 ML	110	540	.270	145.22	0.0000	.8056
12 LEACH OF 20 ML	294	834	.420	144.78	.0075	.8032
13 LEACH OF 20 ML	330	1164	.480	144.17	.0105	.7998
14 LEACH OF 20 ML	729	1893	.900	142.35	.0315	.7897

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .737
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.345 GM)			130.44	1543.72		
1 LEACH OF 20 ML	1	1	1.860	1540.47	.0562	.9979
2 LEACH OF 20 ML	1	2	1.500	1538.25	.0382	.9965
3 LEACH OF 20 ML	1	3	1.020	1537.43	.0142	.9959
4 LEACH OF 20 ML	6	9	.737	1537.43	0.0000	.9959
5 LEACH OF 20 ML	4	13	1.380	1535.57	.0322	.9947
6 LEACH OF 20 ML	21	34	1.260	1534.05	.0262	.9937
7 LEACH OF 20 ML	39	73	.737	1534.05	0.0000	.9937
8 LEACH OF 20 ML	87	160	83.700	1293.58	4.1482	.8380
9 LEACH OF 20 ML	130	290	159.480	833.45	7.9372	.5399
10 LEACH OF 20 ML	140	430	72.300	626.02	3.5782	.4055
11 LEACH OF 20 ML	110	540	25.140	555.29	1.2202	.3597
12 LEACH OF 20 ML	294	834	23.760	488.55	1.1512	.3165
13 LEACH OF 20 ML	330	1164	16.800	441.99	.8032	.2863
14 LEACH OF 20 ML	729	1893	23.520	375.95	1.1392	.2435

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

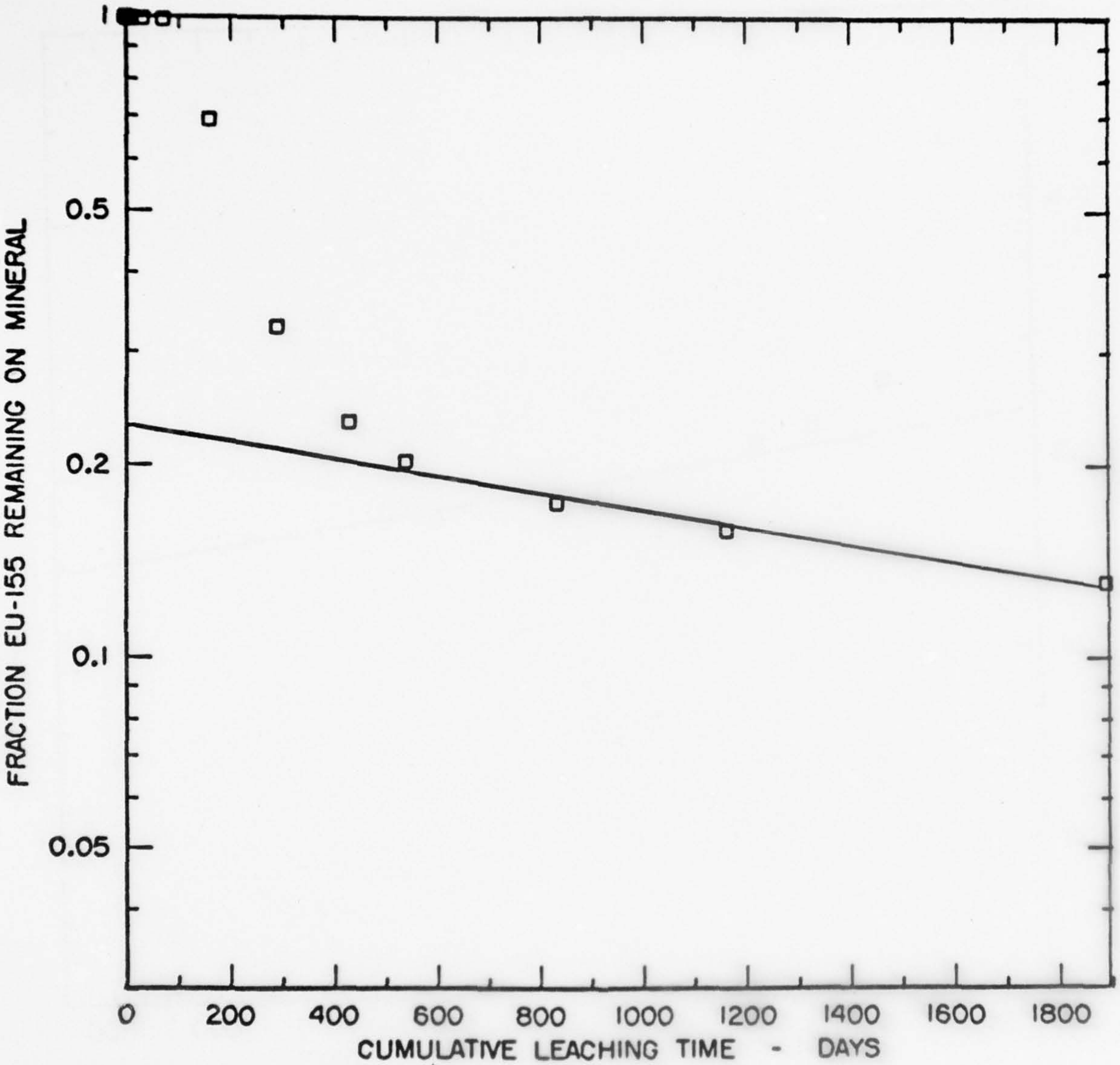

Figure 18. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 10.

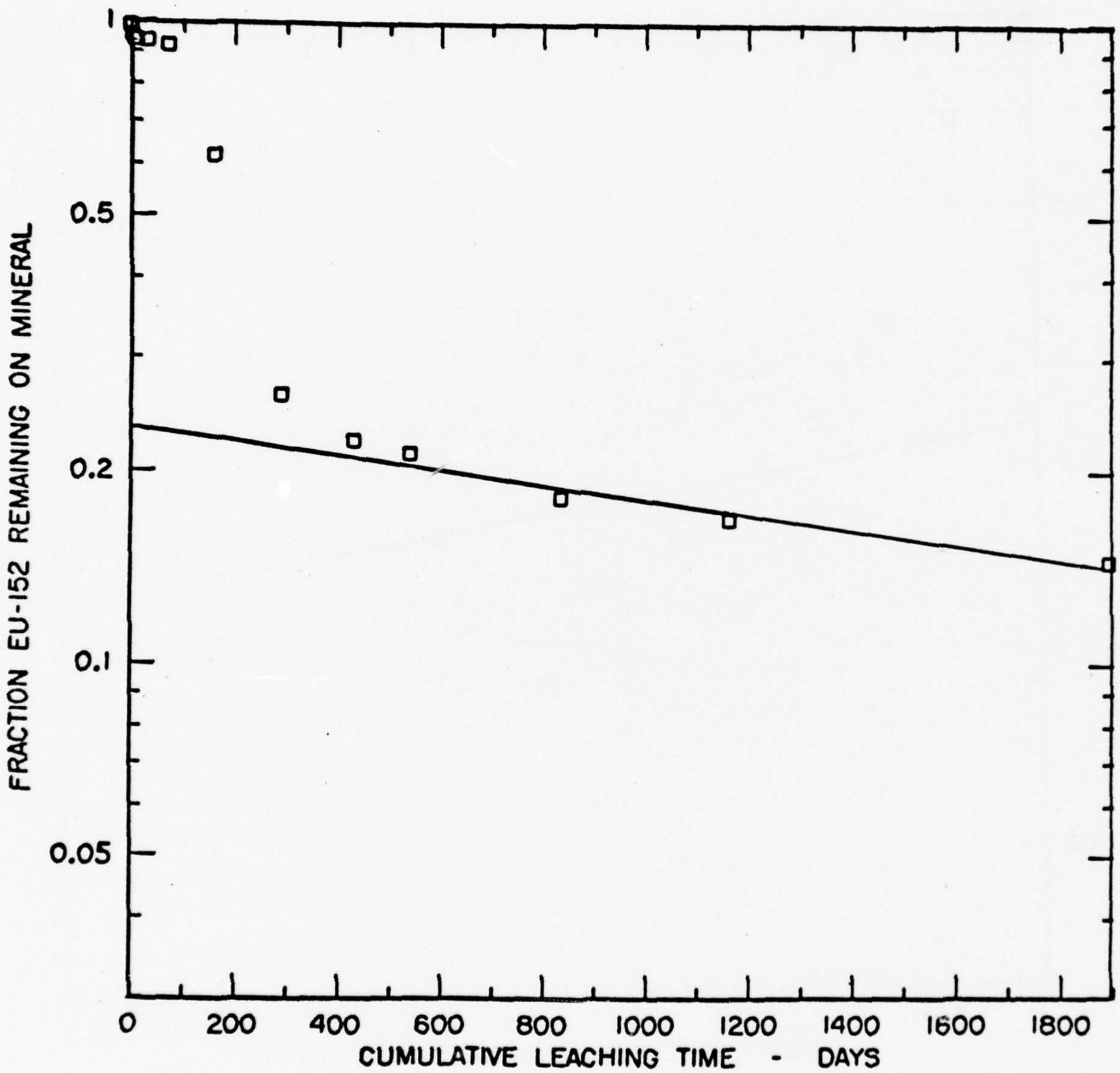

Figure 19. Leaching of Eu-152 from SMALL BOY Fallout.
Data obtained from Table 10.

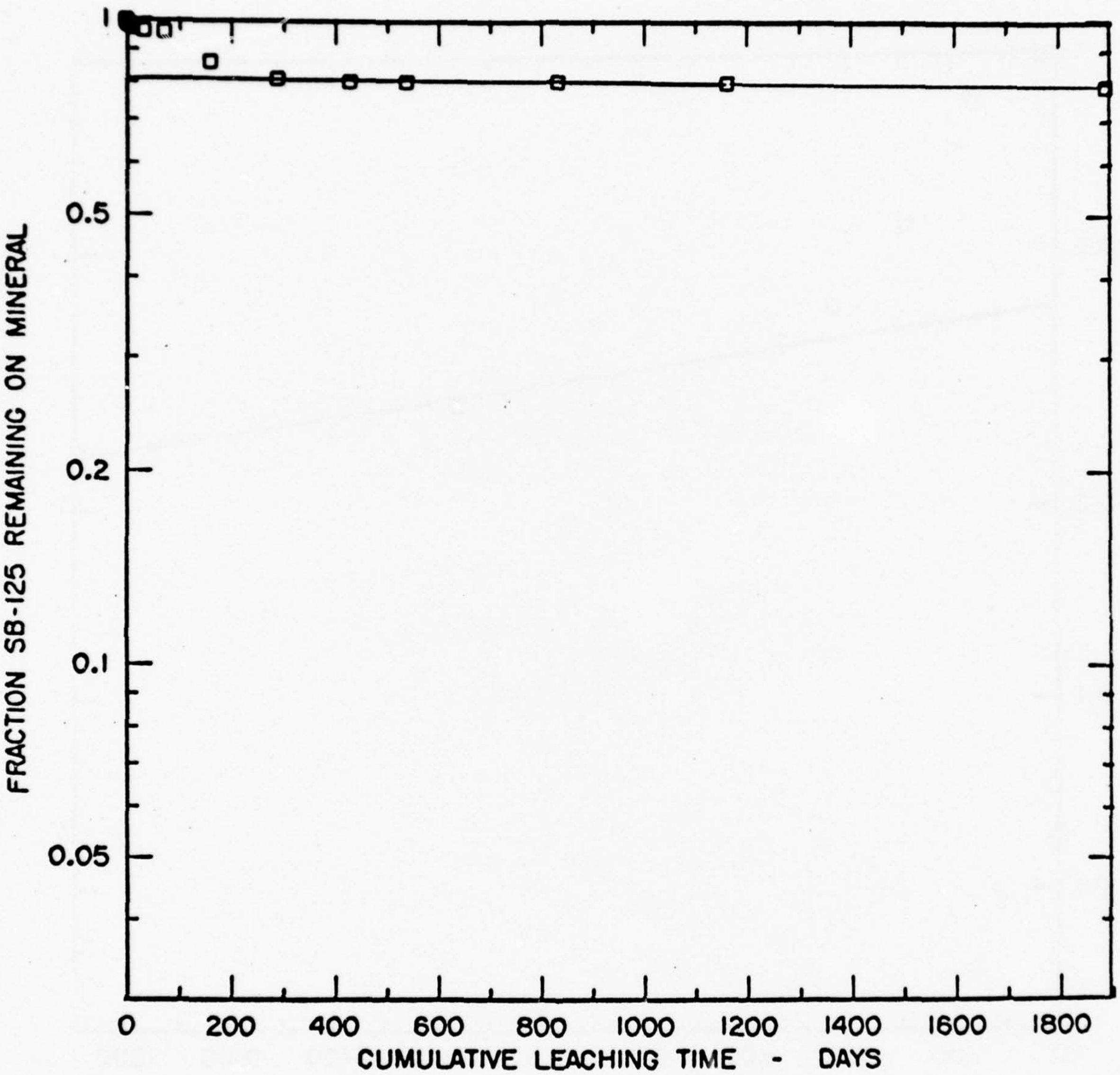

Figure 20. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 10.

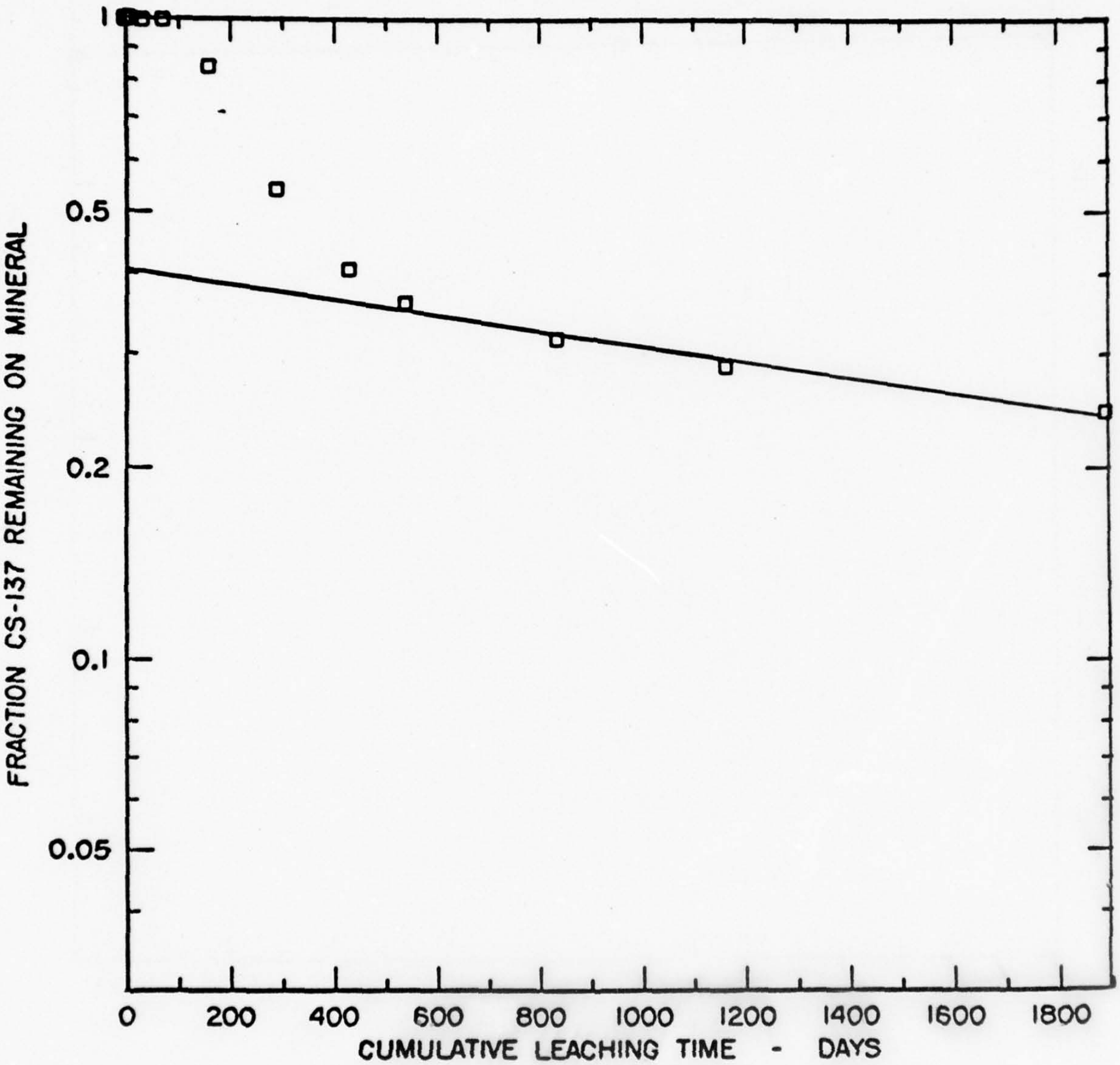

Figure 21. Leaching of Cs-137 from SMALL BOY Fallout.
Data obtained from Table 10.

Table 11

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH
THERMAL TREATMENT 20 C
PARTICLE SIZE 350 - 177 MICRONS
COUNTING DATE 25 MAR. 1975

STANDARD 40000.000 C/M
BACKGROUND .180 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.667 GM)			13.02	258.44		
1 LEACH OF 20 ML	1	1	1.920	255.83	.0870	.9899
2 LEACH OF 20 ML	1	2	1.440	253.94	.0630	.9826
3 LEACH OF 20 ML	1	3	.600	253.31	.0210	.9802
4 LEACH OF 20 ML	6	9	2.400	249.99	.1110	.9673
5 LEACH OF 20 ML	4	13	1.740	247.65	.0780	.9582
6 LEACH OF 20 ML	21	34	3.420	242.79	.1620	.9394
7 LEACH OF 20 ML	39	73	2.880	238.74	.1350	.9238
8 LEACH OF 20 ML	87	160	104.580	82.22	5.2200	.3181
9 LEACH OF 20 ML	130	290	10.440	66.84	.5130	.2586
10 LEACH OF 20 ML	140	430	6.480	57.39	.3150	.2221
11 LEACH OF 20 ML	110	540	5.580	49.30	.2700	.1907
12 LEACH OF 20 ML	294	834	6.900	39.22	.3360	.1518
13 LEACH OF 20 ML	330	1164	7.380	28.43	.3600	.1100
14 LEACH OF 20 ML	729	1893	6.300	19.25	.3060	.0745

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .180
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.667 GM)			1.62	13.04		
1 LEACH OF 20 ML	1	1	.540	12.50	.0180	.9586
2 LEACH OF 20 ML	1	2	.180	12.50	0.0000	.9586
3 LEACH OF 20 ML	1	3	.420	12.14	.0120	.9310
4 LEACH OF 20 ML	6	9	.600	11.51	.0210	.8828
5 LEACH OF 20 ML	4	13	.840	10.52	.0330	.8069
6 LEACH OF 20 ML	21	34	.420	10.16	.0120	.7793
7 LEACH OF 20 ML	39	73	.660	9.45	.0240	.7241
8 LEACH OF 20 ML	87	160	4.080	3.60	.1950	.2759
9 LEACH OF 20 ML	130	290	.180	3.60	0.0000	.2759
10 LEACH OF 20 ML	140	430	.240	3.51	.0030	.2690
11 LEACH OF 20 ML	110	540	.660	2.79	.0240	.2138
12 LEACH OF 20 ML	294	834	.180	2.79	0.0000	.2138
13 LEACH OF 20 ML	330	1164	.180	2.79	0.0000	.2138
14 LEACH OF 20 ML	729	1893	.600	2.16	.0210	.1655

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

Table 11 (Concluded)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH
THERMAL TREATMENT 20 C
PARTICLE SIZE 350 - 177 MICRONS
COUNTING DATE 25 MAR. 1975

STANDARD. 40000.000 C/M
BACKGROUND .300 C/M
LEACHING STARTED 11 NOV. 1969

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.667 GM)			6.54	15.83		
1 LEACH OF 20 ML	1	1	.420	15.65	.0060	.9886
2 LEACH OF 20 ML	1	2	.900	14.75	.0300	.9318
3 LEACH OF 20 ML	1	3	.420	14.57	.0060	.9205
4 LEACH OF 20 ML	6	9	.720	13.94	.0210	.8807
5 LEACH OF 20 ML	4	13	.300	13.94	0.0000	.8807
6 LEACH OF 20 ML	21	34	.960	12.95	.0330	.8182
7 LEACH OF 20 ML	39	73	.300	12.95	0.0000	.8182
8 LEACH OF 20 ML	87	160	.840	12.14	.0270	.7670
9 LEACH OF 20 ML	130	290	.420	11.96	.0060	.7557
10 LEACH OF 20 ML	140	430	.540	11.60	.0120	.7330
11 LEACH OF 20 ML	110	540	.540	11.24	.0120	.7102
12 LEACH OF 20 ML	294	834	.600	10.79	.0150	.6818
13 LEACH OF 20 ML	330	1164	.720	10.16	.0210	.6420
14 LEACH OF 20 ML	729	1893	.840	9.36	.0270	.5909

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .300
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.667 GM)			18.84	140.96		
1 LEACH OF 20 ML	1	1	.300	140.96	0.0000	1.0000
2 LEACH OF 20 ML	1	2	.960	139.97	.0330	.9930
3 LEACH OF 20 ML	1	3	.480	139.70	.0090	.9911
4 LEACH OF 20 ML	6	9	1.080	138.53	.0390	.9828
5 LEACH OF 20 ML	4	13	1.020	137.45	.0360	.9751
6 LEACH OF 20 ML	21	34	.900	136.55	.0300	.9687
7 LEACH OF 20 ML	39	73	.900	135.65	.0300	.9623
8 LEACH OF 20 ML	87	160	18.840	107.86	.9270	.7652
9 LEACH OF 20 ML	130	290	19.800	78.62	.9750	.5578
10 LEACH OF 20 ML	140	430	9.420	64.95	.4560	.4608
11 LEACH OF 20 ML	110	540	6.840	55.14	.3270	.3912
12 LEACH OF 20 ML	294	834	6.780	45.43	.3240	.3223
13 LEACH OF 20 ML	330	1164	6.720	35.80	.3210	.2540
14 LEACH OF 20 ML	729	1893	5.640	27.80	.2670	.1972

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

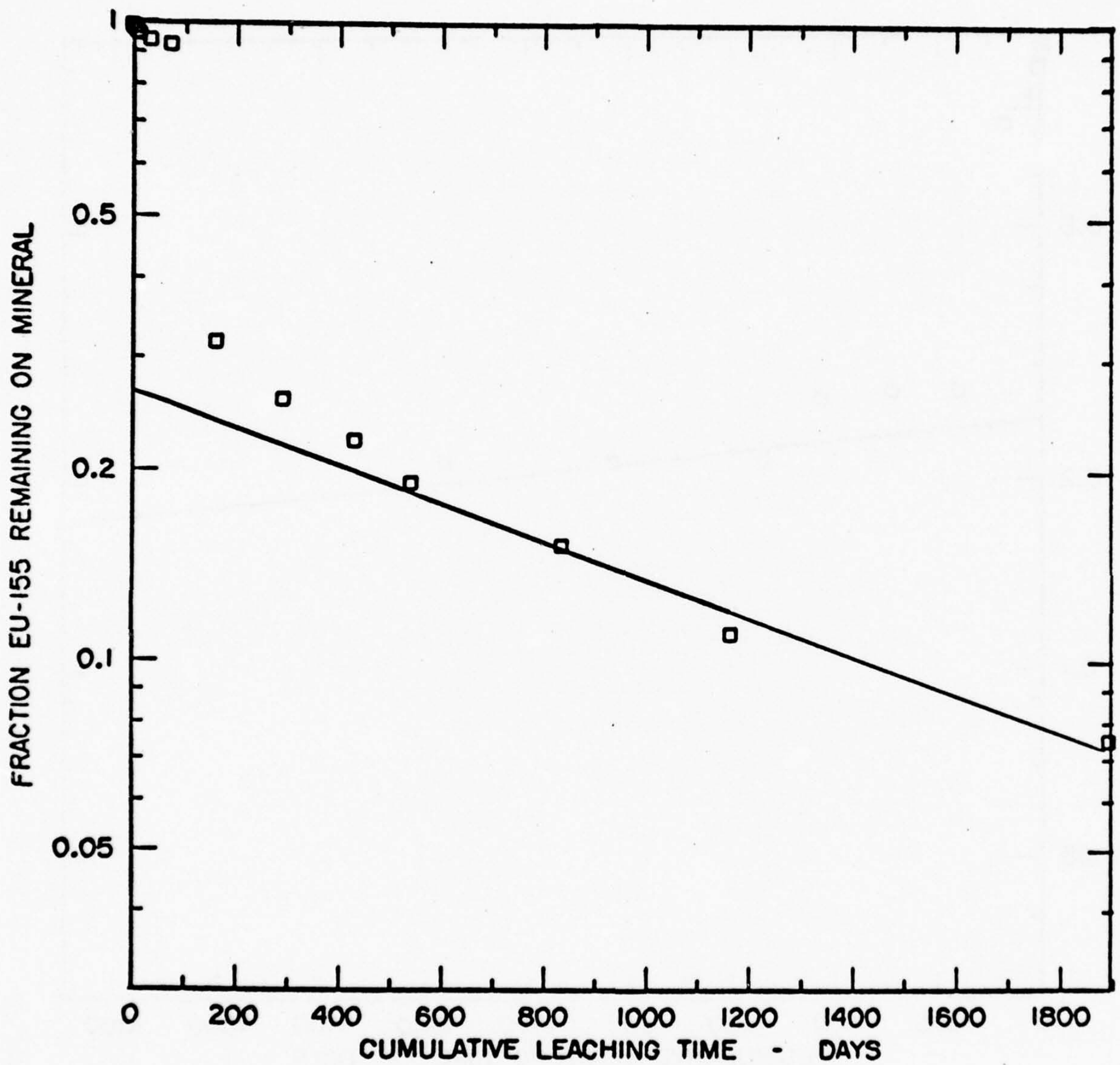

Figure 22. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 11.

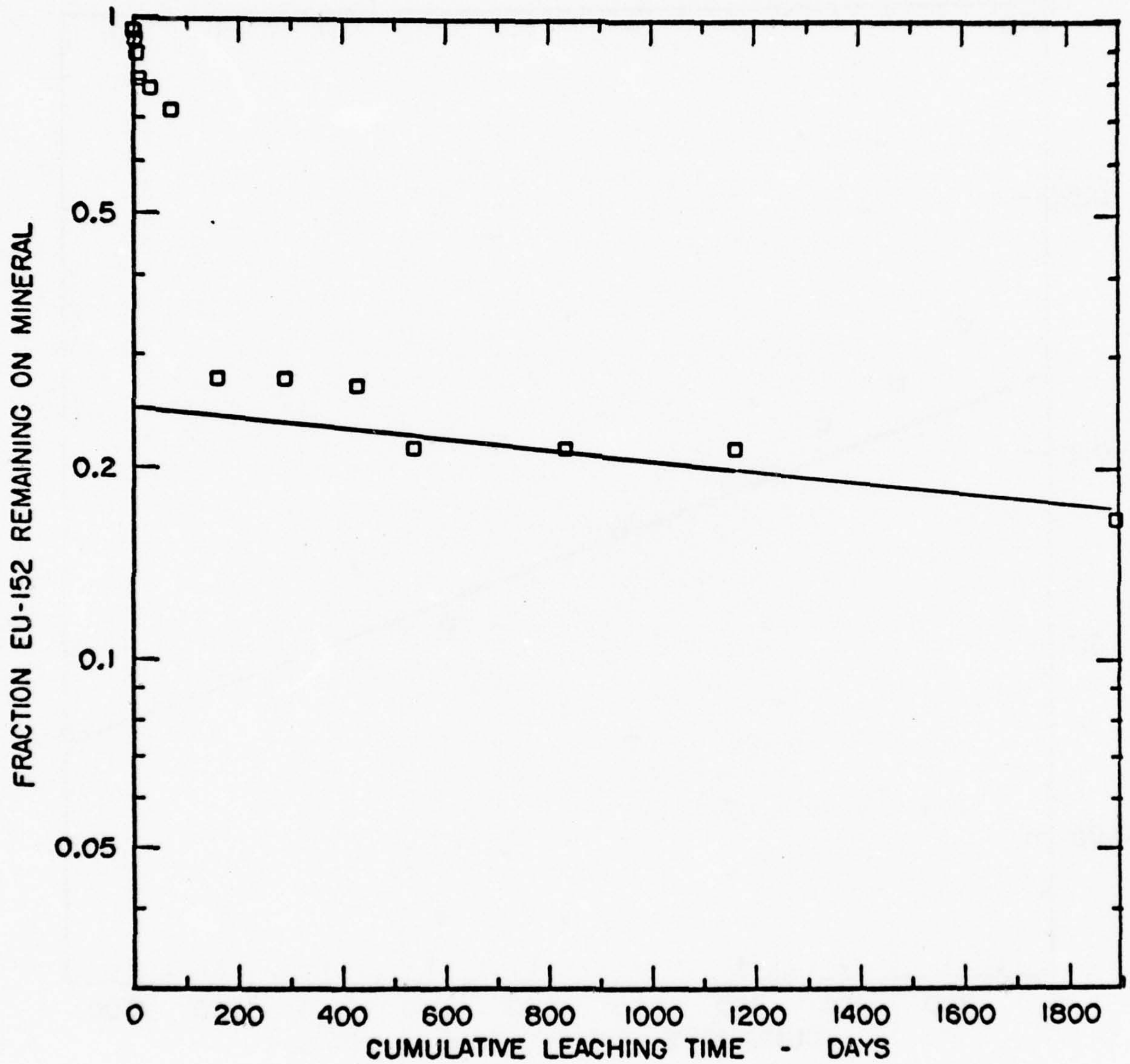

Figure 23. Leaching of Eu-152 from SMALL BOY Fallout. Data obtained from Table 11.

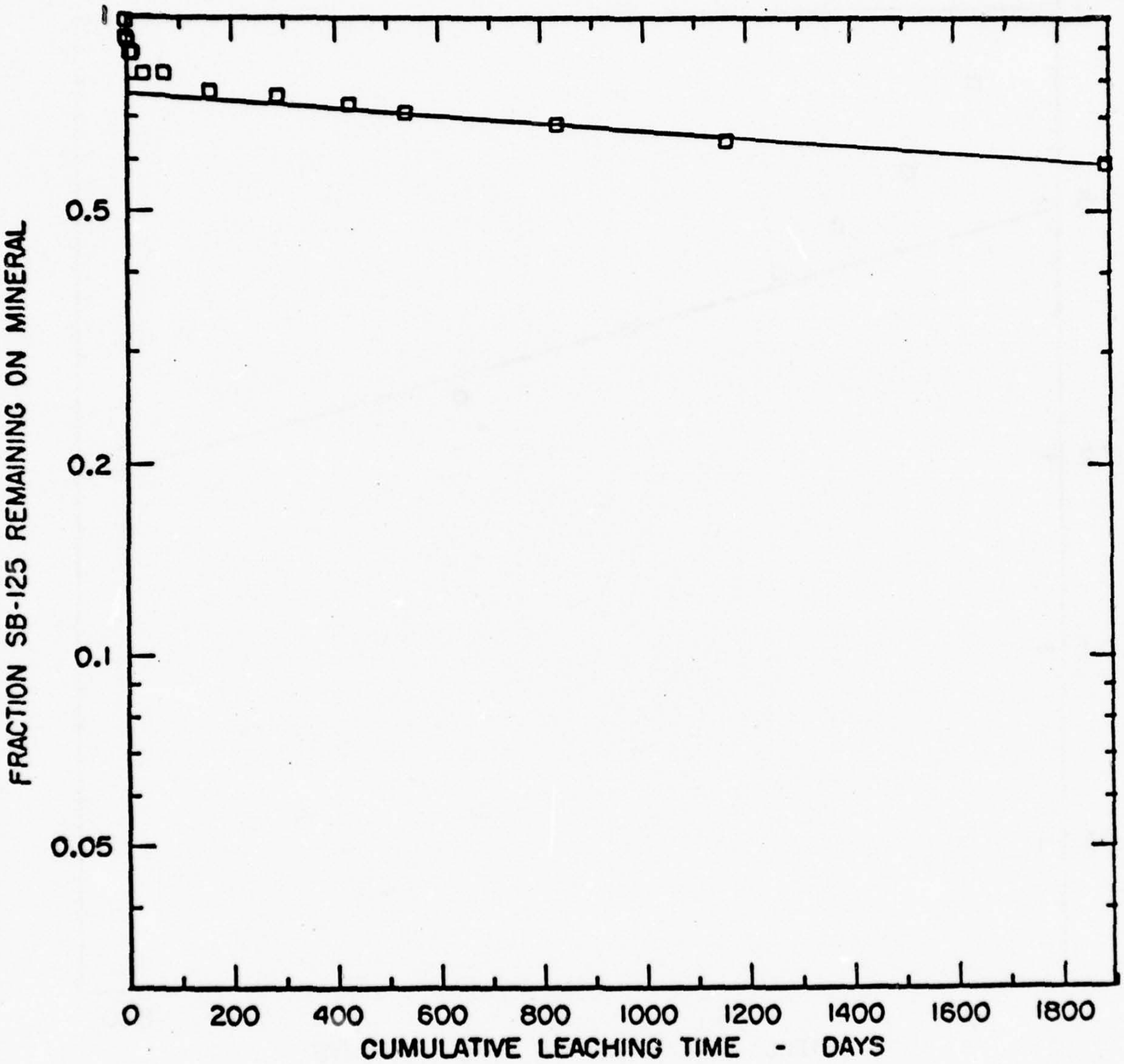

Figure 24. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 11.

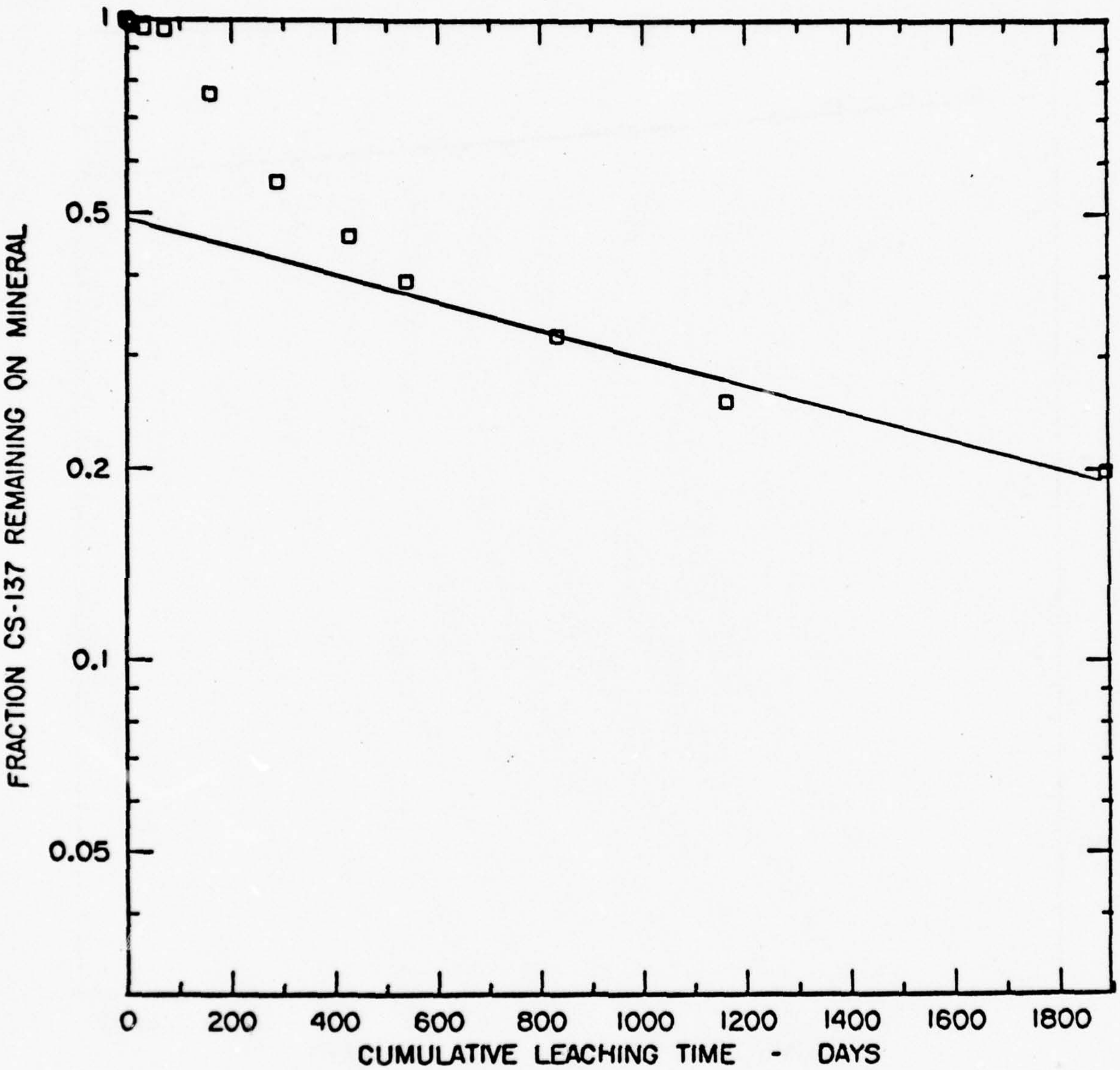

Figure 25. Leaching of Cs-137 from SMALL BOY Fallout. Data obtained from Table 11.

Table 12

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH — STANDARD 40000.000 C/M
THERMAL TREATMENT 20 C — BACKGROUND 2.440 C/M
PARTICLE SIZE 88 - 44 MICRONS — LEACHING STARTED 11 NOV. 1969
COUNTING DATE 27 MAR. 1975

CONCENTRATION OF EU-155

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.405 GM)			5.28	40.20		
1 LEACH OF 20 ML	1	1	3.180	38.37	.0370	.9545
2 LEACH OF 20 ML	1	2	2.440	38.37	0.0000	.9545
3 LEACH OF 20 ML	1	3	2.440	38.37	0.0000	.9545
4 LEACH OF 20 ML	6	9	4.140	34.17	.0850	.8501
5 LEACH OF 20 ML	4	13	2.940	32.94	.0250	.8194
6 LEACH OF 20 ML	21	34	2.440	32.94	0.0000	.8194
7 LEACH OF 20 ML	39	73	2.440	32.94	0.0000	.8194
8 LEACH OF 20 ML	87	160	5.760	24.74	.1660	.6155
9 LEACH OF 20 ML	130	290	3.360	22.47	.0460	.5590
10 LEACH OF 20 ML	140	430	6.000	13.68	.1780	.3403
11 LEACH OF 20 ML	110	540	2.700	13.04	.0130	.3243
12 LEACH OF 20 ML	294	834	2.440	13.04	0.0000	.3243
13 LEACH OF 20 ML	330	1164	3.480	10.47	.0520	.2604
14 LEACH OF 20 ML	729	1893	3.840	7.01	.0700	.1744

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .367
CONCENTRATION OF EU-152

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.405 GM)			1.14	12.83		
1 LEACH OF 20 ML	1	1	.720	11.96	.0176	.9322
2 LEACH OF 20 ML	1	2	.780	10.94	.0206	.8528
3 LEACH OF 20 ML	1	3	.840	9.78	.0236	.7619
4 LEACH OF 20 ML	6	9	.370	9.77	.0001	.7614
5 LEACH OF 20 ML	4	13	.840	8.60	.0236	.6705
6 LEACH OF 20 ML	21	34	.370	8.60	.0001	.6700
7 LEACH OF 20 ML	39	73	.540	8.17	.0086	.6368
8 LEACH OF 20 ML	87	160	.960	6.71	.0296	.5228
9 LEACH OF 20 ML	130	290	.420	6.58	.0026	.5127
10 LEACH OF 20 ML	140	430	.370	6.57	.0001	.5123
11 LEACH OF 20 ML	110	540	.780	5.56	.0206	.4329
12 LEACH OF 20 ML	294	834	1.260	3.35	.0446	.2612
13 LEACH OF 20 ML	330	1164	.780	2.33	.0206	.1818
14 LEACH OF 20 ML	729	1893	.540	1.91	.0086	.1486

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

Table 12 (Concluding)

LEACHING OF PARTICLES OF FALLOUT FROM SMALL BOY

LEACHING SOLUTION WAS HOH — STANDARD 40000.000 C/M
THERMAL TREATMENT 20 C — BACKGROUND .190 C/M
PARTICLE SIZE 88 - 44 MICRONS — LEACHING STARTED 11 NOV. 1969
COUNTING DATE 27 MAR. 1975

CONCENTRATION OF SB-125

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.405 GM)			2.10	14.40		
1 LEACH OF 20 ML	1	1	.190	14.40	0.0000	1.0000
2 LEACH OF 20 ML	1	2	.600	13.38	.0205	.9297
3 LEACH OF 20 ML	1	3	1.080	11.19	.0445	.7770
4 LEACH OF 20 ML	6	9	.190	11.19	0.0000	.7770
5 LEACH OF 20 ML	4	13	1.020	9.14	.0415	.6346
6 LEACH OF 20 ML	21	34	.420	8.57	.0115	.5952
7 LEACH OF 20 ML	39	73	.300	8.30	.0055	.5763
8 LEACH OF 20 ML	87	160	.540	7.43	.0175	.5163
9 LEACH OF 20 ML	130	290	.300	7.16	.0055	.4974
10 LEACH OF 20 ML	140	430	.360	6.74	.0085	.4683
11 LEACH OF 20 ML	110	540	.190	6.74	0.0000	.4683
12 LEACH OF 20 ML	294	834	.420	6.17	.0115	.4288
13 LEACH OF 20 ML	330	1164	.780	4.72	.0295	.3276
14 LEACH OF 20 ML	729	1893	.190	4.72	0.0000	.3276

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

BACKGROUND .895
CONCENTRATION OF CS-137

	LEACHING TIME DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (.405 GM)			5.82	18.70		
1 LEACH OF 20 ML	1	1	.900	18.69	.0002	.9993
2 LEACH OF 20 ML	1	2	1.020	18.38	.0063	.9828
3 LEACH OF 20 ML	1	3	.900	18.37	.0002	.9822
4 LEACH OF 20 ML	6	9	.900	18.36	.0002	.9815
5 LEACH OF 20 ML	4	13	1.020	18.05	.0063	.9650
6 LEACH OF 20 ML	21	34	.960	17.89	.0033	.9564
7 LEACH OF 20 ML	39	73	1.140	17.28	.0122	.9241
8 LEACH OF 20 ML	87	160	1.860	14.90	.0482	.7967
9 LEACH OF 20 ML	130	290	.900	14.89	.0002	.7960
10 LEACH OF 20 ML	140	430	1.140	14.28	.0122	.7637
11 LEACH OF 20 ML	110	540	.900	14.27	.0002	.7630
12 LEACH OF 20 ML	294	834	1.680	12.33	.0392	.6594
13 LEACH OF 20 ML	330	1164	.900	12.32	.0002	.6587
14 LEACH OF 20 ML	729	1893	.960	12.16	.0033	.6502

0.IN HCL WAS USED FROM THE 8TH LEACHING TO THE 14TH

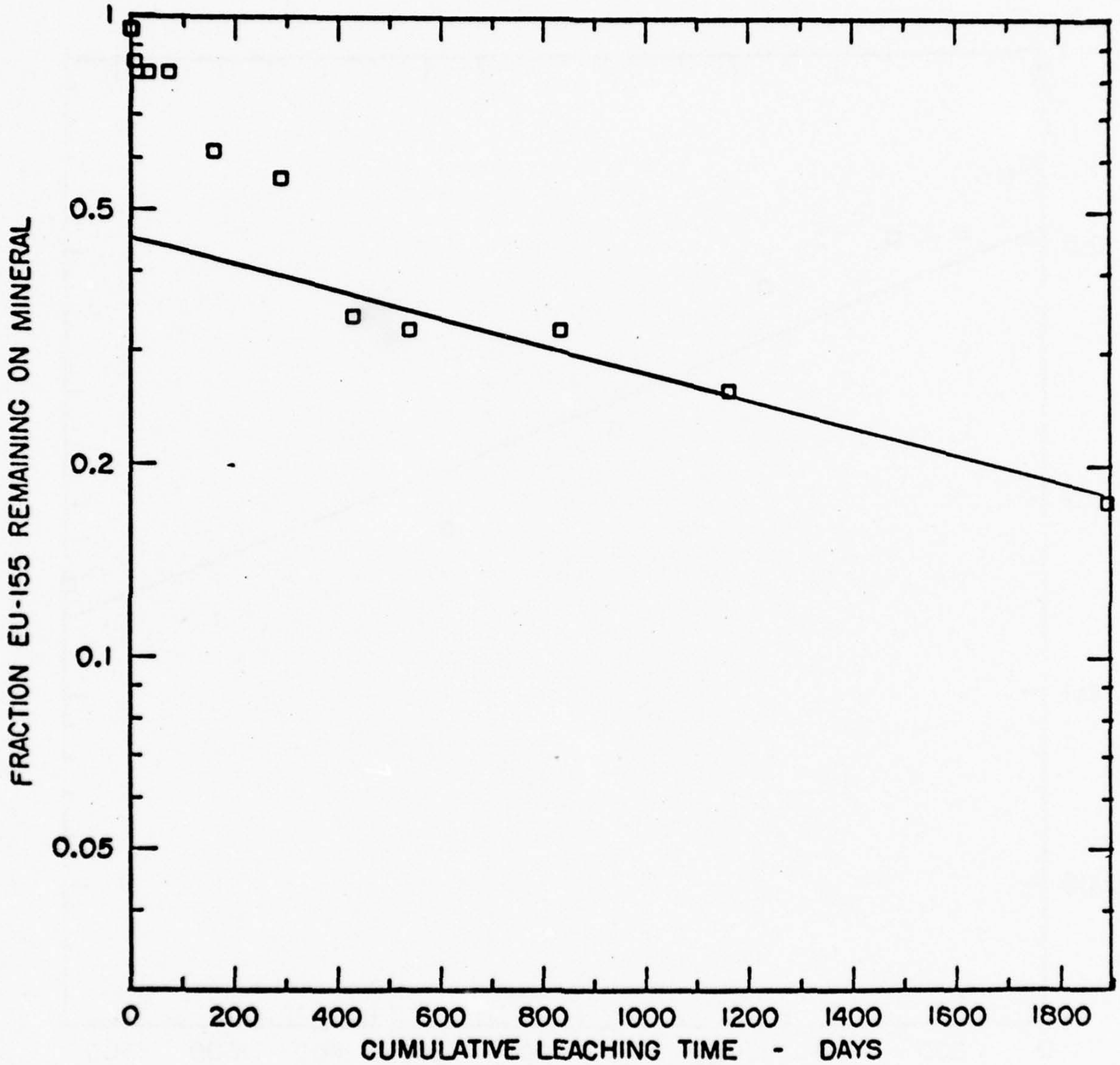

Figure 26. Leaching of Eu-155 from SMALL BOY Fallout.
Data obtained from Table 12.

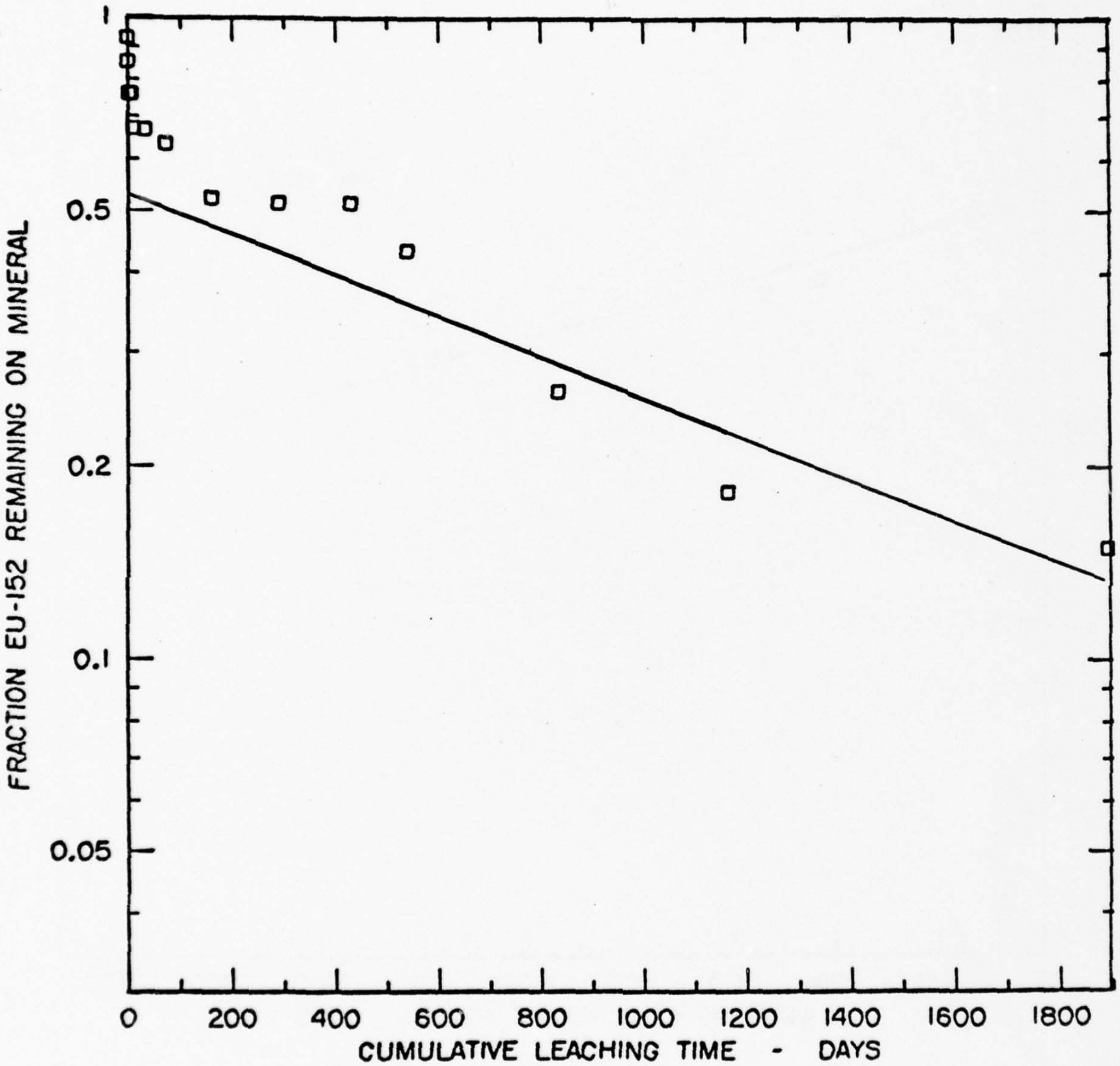

Figure 27. Leaching of Eu-152 from SMALL BOY Fallout. Data obtained from Table 12.

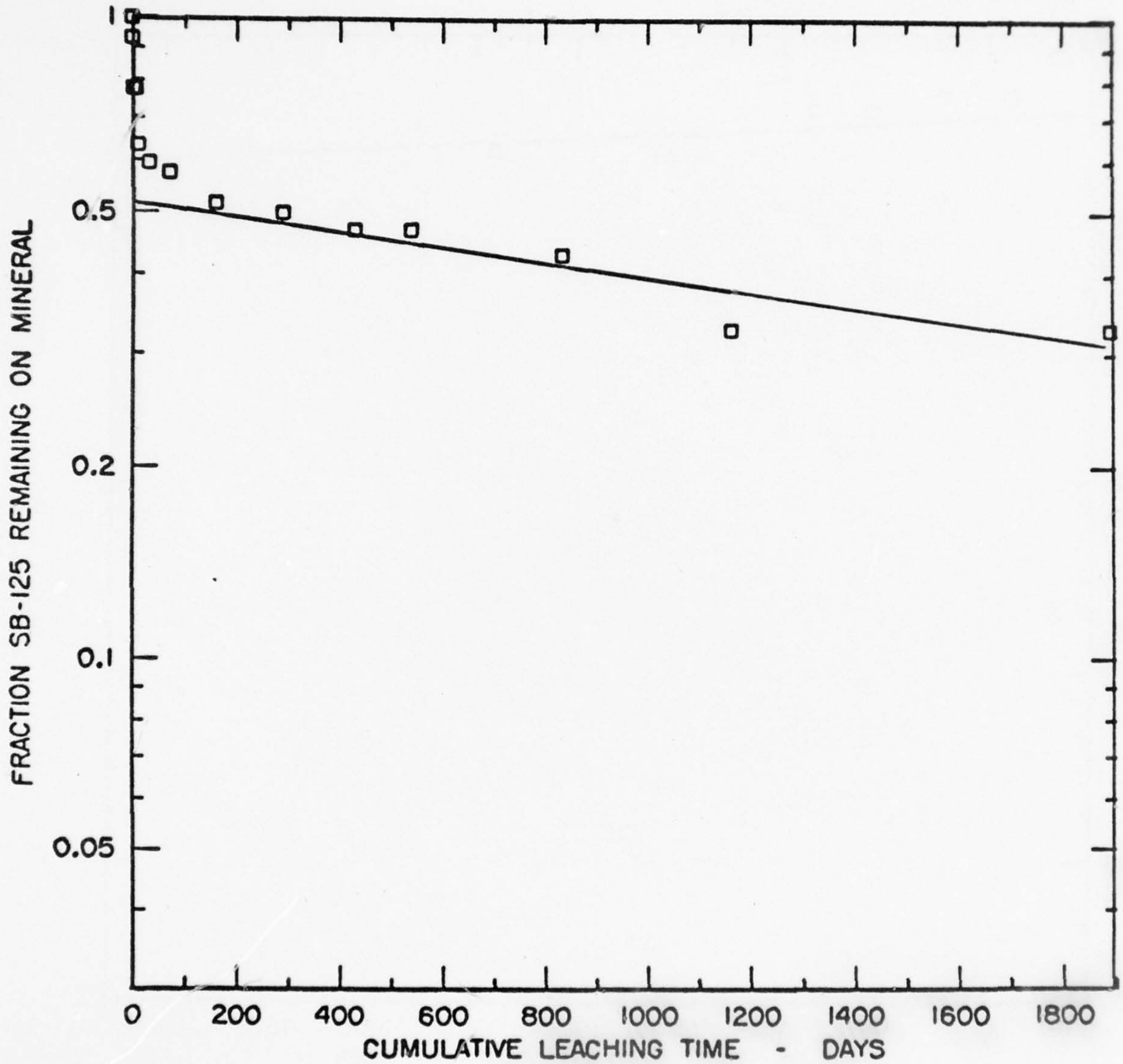

Figure 28. Leaching of Sb-125 from SMALL BOY Fallout. Data obtained from Table 12.

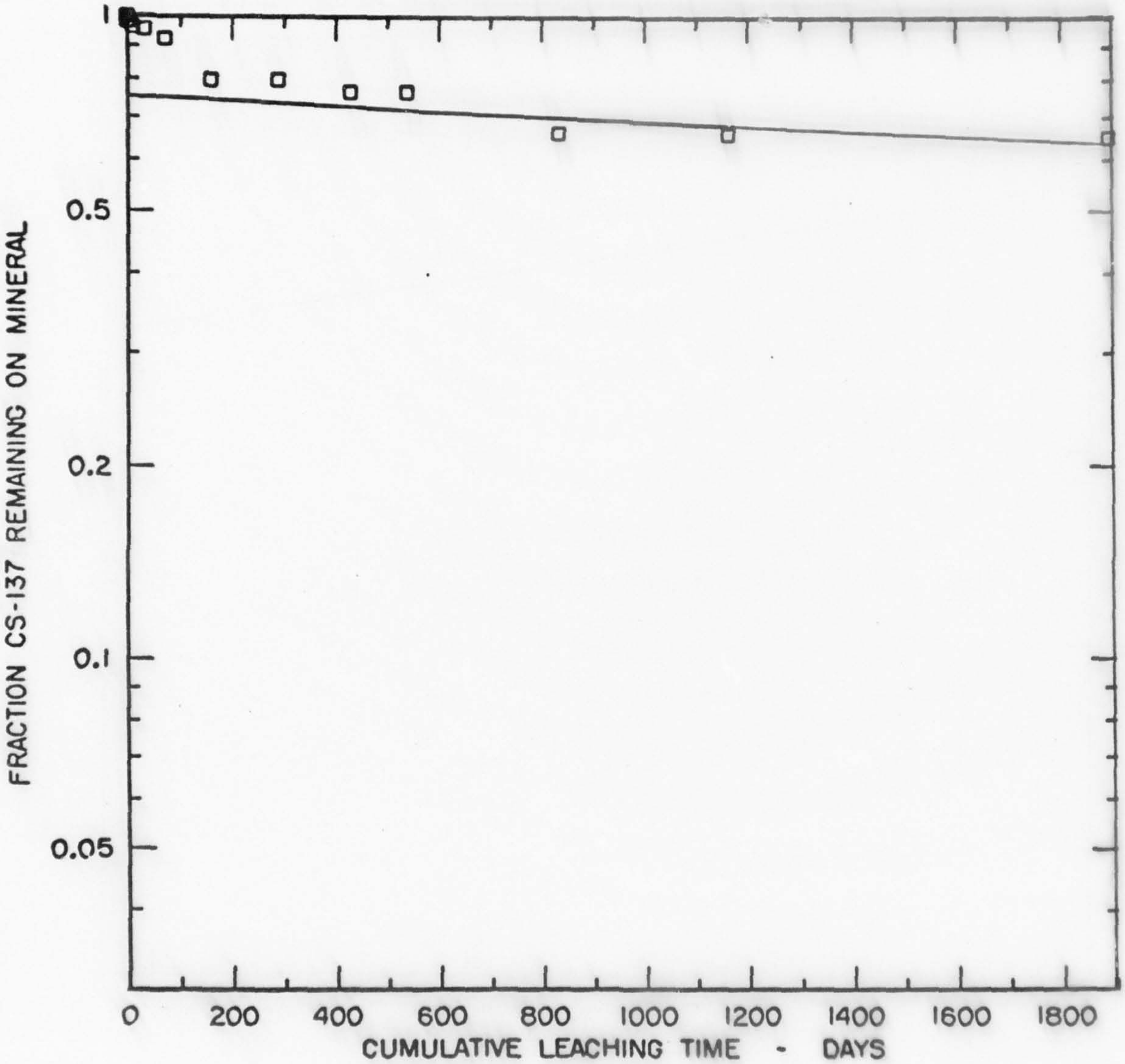

Figure 29. Leaching of Cs-137 from SMALL BOY Fallout. Data obtained from Table 12.

The constants τ and D in equation (4) for the radionuclides Sb-125, Cs-137, Eu-152, and Eu-155 in SMALL BOY fallout are presented in Table 13. Table 14 lists the characteristic photon that was used in the analysis, the efficiency (counts per disintegration) for the sample geometry and the instrumentation, and the latest published half-life value for each of these radionuclides. The specific activity (c/m/g) and equivalent fissions/g are reported in Table 15. Since Cs-137 was considered a volatile mass chain,[6] Sb-125 an intermediate mass chain, and Eu-155 a refractory mass chain, these data are pertinent to a review of the theory of fallout formation. Eu-152 is a neutron induced activity from the low natural concentration of europium in the Nevada soil. The data suggest that the particles larger than 350 microns came from a different source than the particles smaller than 350 microns or were exposed to a neutron flux that differed by an order of magnitude. Eu-155 was an unexpected contributor to 13-year-old fission product since in Reference 6 it was listed as having a 657-day half-life rather than the 1,800 days shown in Table 14. The yields for mass chain 125 in Reference 6 could not account for the large activity of Sb-125; the activity was more in accord with the yields reported in Reference 20.

In addition to the detailed results presented in Tables 6-12 for SMALL BOY fallout, the leaching after 1,893 days can be summarized as follows:

1. Water was about as effective as 0.1$\underline{N}$ HCl in removing each of the measured radionuclides.

2. Leaching of Eu-152 and Eu-155 was not significantly different. From 83-95 percent of the activity was leached in all cases.

3. Cs-137 was more readily leached from large particles than from small particles (50 percent).

4. Sb-125 was more readily leached from small particles (65 percent) than from large particles (20 percent).

Table 13

RADIONUCLIDE DIFFUSION CONSTANTS FOR SMALL BOY

Particle Diameter			Sb-125		Cs-137		Eu-152		Eu-155	
Range (micron)	Average (micron)	Leachant	τ	D (micron^2 day^{-1})	τ	D (micron^2 day^{-1})	τ	D (micron^2 day^{-1})	τ	D (micron^2 day^{-1})
2830-1410	1900	HCl	76,900	4.76	9,200	39.8	10,100	36.3	8,490	43.1
710- 350	540	HCl	68,900	0.429	10,400	2.84	4,880	6.05	10,900	2.72
177- 88	135	HCl	12,000	0.153	4,360	0.424	--	--	2,270	0.812
< 44	20	HCl	13,200	0.00306	8,820	0.00459	3,170	0.013	4,490	0.00903
1410- 710	985	H_2O	153,000	0.640	8,240	11.9	8,610	11.4	7,400	13.3
350- 177	246	H_2O	16,900	0.364	4,600	1.33	11,700	0.526	3,310	1.85
88- 44	63	H_2O	8,470	0.0475	24,900	0.0161	3,120	0.129	4,690	0.0857

Table 14

COUNTING EFFICIENCY FOR 0-1 MeV
(Applies to SMALL BOY, SHASTA, SEDAN)

Nuclide	Photon Energy* (MeV)	Efficiency** (c/d)	Half-Life*** (days)
Sb-125	0.426	0.00567	9.965×10^{2}
Cs-137	0.661	0.00964	1.096×10^{4}
Eu-152	0.344	0.00763	5.117×10^{3}
Eu-155	0.086	0.0261	1.800×10^{3}
Rh-102m	0.475	0.0148	1.055×10^{3}

*Characteristic photon peak used in analysis.

**Counts per disintegration.

***Half-life used in calculations.

Table 15

RADIONUCLIDE ACTIVITY OF SMALL BOY FALLOUT

Particle Diameter (micron)	Sb-125 Activity (c/m/g)	Sb-125 f* (fissions/g)	Cs-137 Activity (c/m/g)	Cs-137 f* (fissions/g)	Eu-152 Activity (c/m/g)	Eu-152 R** (capture/fissions)	Eu-155 Activity (c/m/g)	Eu-155 f* (fissions/g)
2830-1410	178	5.71E14	1560	2.95E14	148	3.35E-4	2090	13.6E14
1410- 710	180	5.79E14	1544	2.92E14	109	2.28E-4	2260	14.7E14
710- 350	225	7.22E14	1793	3.39E14	126	1.95E-4	3059	19.9E14
550- 177	15.8	.508E14	141	.266E14	13.0	2.39E-4	258	1.68E14
177- 88	24.8	.796E14	116	.220E14	35.6	7.34E-4	229	1.49E14
88- 44	14.4	.462E14	18.7	.035E14	12.8	15.1E-4	40.2	.262E14
< 44	13.1	.422E14	44.7	.085E14	13.5	9.86E-4	64.7	.421E14

*Fissions calculated from mass chain yields reported in Dolan, P. J., "Calculated Abundances, and Activities of the Products of High Energy Neutron Fission of Uranium-238," DASA 525, May 1959 (Reference 20).

**Captures/fission of Eu(152/155).

These data should be useful in estimating the fraction of fission product radionuclides that would be available for entry into biological systems. The behavior of Sr-90 would be a most useful addition, and all samples have been retained, should someone desire to sponsor the radiochemical analysis and the beta counting required in Sr-90 determinations.

Leaching of Cs-134 Tagged Synthetic Fallout

The synthetic fallout consisted of a batch heated to 1200°C, a second batch heated to 900°C, and a third batch that was unheated (20°C). Inspection of the counting data in Tables 16, 17, and 18 shows that while more than 90 percent of the Cs-134 was leached from the 900°C and 20°C batches, about 60 percent was removed by 2,995 days of leaching from the 1200°C batch. This covers about the same range of leaching as reported above for Cs-137 in SMALL BOY fallout. The data were further analyzed exactly as described for SMALL BOY, and the resulting straight lines in Figures 30, 31, and 32 were used to calculate the diffusion constants τ and D, which are reported in Table 19.

Table 16

EIGHT YEAR LEACHING OF CESIUM FROM SYNTHETIC FALLOUT

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 20 C
PARTICLE SIZE 175 - 88 MICRONS
COUNTING DATE 22 APR. 1975

STANDARD 40000.000 C/M
BACKGROUND 1.000 C/M
LEACHING STARTED 6 FEB. 1967

	LEACHING TIME			CONCENTRATION OF CS-134		
	DELTA TIME (DAYS)	SUM TIME (DAYS)	ACTIVITY SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (2.000 GM)			240.00	1917.60		
1 LEACH OF 20 ML	1	1	2126.300	854.95	106.2650	.4458
2 LEACH OF 20 ML	1	2	521.800	594.55	26.0400	.3100
3 LEACH OF 20 ML	1	3	215.700	487.20	10.7350	.2541
4 LEACH OF 20 ML	1	4	99.900	437.75	4.9450	.2283
5 LEACH OF 20 ML	3	7	87.900	394.30	4.3450	.2056
6 LEACH OF 20 ML	2	9	30.700	379.45	1.4850	.1979
7 LEACH OF 20 ML	5	14	88.100	335.90	4.3550	.1752
8 LEACH OF 20 ML	10	24	34.100	319.35	1.6550	.1665
9 LEACH OF 20 ML	2	26	20.200	309.75	.9600	.1615
10 LEACH OF 20 ML	2	28	12.000	304.25	.5500	.1587
11 LEACH OF 20 ML	2	30	23.400	293.05	1.1200	.1528
12 LEACH OF 20 ML	20	50	63.300	261.90	3.1150	.1366
13 LEACH OF 20 ML	14	64	26.100	249.35	1.2550	.1300
14 LEACH OF 20 ML	24	88	33.600	233.05	1.6300	.1215
15 LEACH OF 20 ML	46	134	41.900	212.60	2.0450	.1109
16 LEACH OF 20 ML	24	158	27.000	199.60	1.3000	.1041
17 LEACH OF 20 ML	32	190	23.300	188.45	1.1150	.0983
18 LEACH OF 20 ML	42	232	12.700	182.60	.5850	.0952
19 LEACH OF 20 ML	31	263	13.100	176.55	.6050	.0921
20 LEACH OF 20 ML	68	331	9.500	172.30	.4250	.0899
21 LEACH OF 20 ML	40	371	7.400	169.10	.3200	.0882
22 LEACH OF 20 ML	43	414	7.000	166.10	.3000	.0866
23 LEACH OF 20 ML	76	490	9.700	161.75	.4350	.0844
24 LEACH OF 20 ML	102	592	15.700	154.40	.7350	.0805
25 LEACH OF 20 ML	94	686	8.200	150.80	.3600	.0786
26 LEACH OF 20 ML	28	714	2.500	150.05	.0750	.0782
27 LEACH OF 20 ML	36	750	2.900	149.10	.0950	.0778
28 LEACH OF 20 ML	332	1082	15.600	141.80	.7300	.0739
29 LEACH OF 20 ML	87	1169	4.400	140.10	.1700	.0731
30 LEACH OF 20 ML	8	1177	9.100	136.05	.4050	.0709
31 LEACH OF 20 ML	262	1439	8.600	132.25	.3800	.0690
32 LEACH OF 20 ML	110	1549	5.300	130.10	.2150	.0678
33 LEACH OF 20 ML	294	1843	12.800	124.20	.5900	.0648
34 LEACH OF 20 ML	330	2173	6.100	121.65	.2550	.0634
35 LEACH OF 20 ML	822	2995	5.300	119.50	.2150	.0623

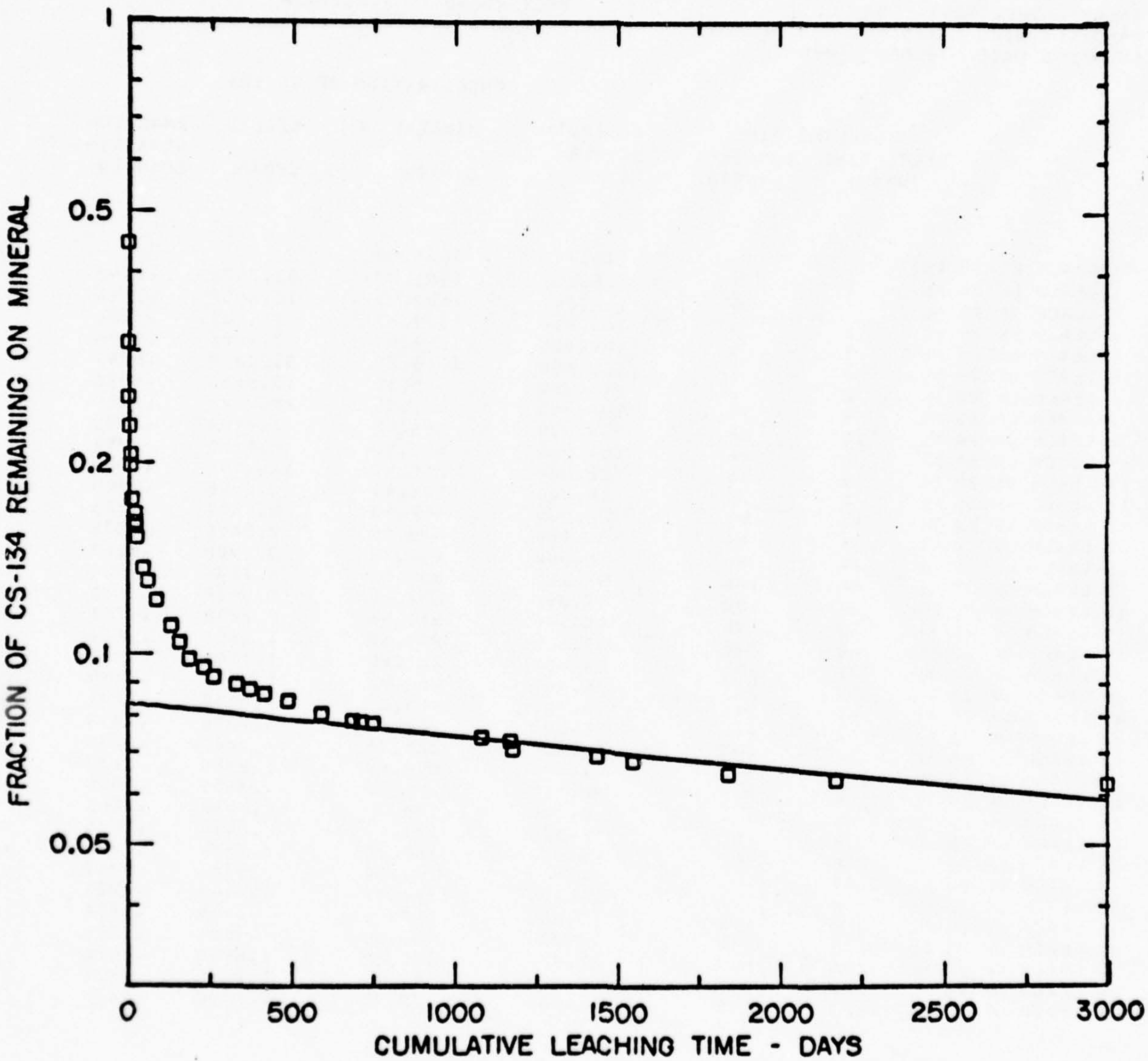

Figure 30. Leaching of Cs-134 at 20 Degrees Thermal Treatment
Data obtained from Table 16.

Table 17

EIGHT YEAR LEACHING OF CESIUM FROM SYNTHETIC FALLOUT

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 900 C
PARTICLE SIZE 175 - 88 MICRONS
COUNTING DATE 8 MAY 1975

STANDARD 40000.000 C/M
BACKGROUND 1.000 C/M
LEACHING STARTED 6 FEB. 1967

	LEACHING TIME		ACTIVITY	CONCENTRATION OF CS-134		
	DELTA TIME (DAYS)	SUM TIME (DAYS)	SAMPLE C/M	MINERAL C/M/GM	LIQUID C/M/ML	FRACTION REMAINING CMIN/CO
MINERAL (2.000 GM)			145.70	1633.80		
1 LEACH OF 20 ML	1	1	665.000	1501.80	33.2000	.6190
2 LEACH OF 20 ML	1	2	202.700	1400.95	10.0850	.7640
3 LEACH OF 20 ML	1	3	143.900	1329.50	7.1450	.7250
4 LEACH OF 20 ML	1	4	149.000	1255.50	7.4000	.6846
5 LEACH OF 20 ML	3	7	421.600	1045.20	21.0300	.5700
6 LEACH OF 20 ML	2	9	280.300	905.55	13.9650	.4938
7 LEACH OF 20 ML	5	14	598.600	606.75	29.8800	.3309
8 LEACH OF 20 ML	10	24	76.400	569.05	3.7700	.3103
9 LEACH OF 20 ML	2	26	57.300	540.90	2.8150	.2950
10 LEACH OF 20 ML	2	28	22.800	530.00	1.0900	.2890
11 LEACH OF 20 ML	2	30	18.200	521.40	.8600	.2843
12 LEACH OF 20 ML	20	50	121.000	461.40	6.0000	.2516
13 LEACH OF 20 ML	14	64	52.600	435.60	2.5800	.2375
14 LEACH OF 20 ML	24	88	62.800	404.70	3.0900	.2207
15 LEACH OF 20 ML	46	134	95.200	357.60	4.7100	.1950
16 LEACH OF 20 ML	24	158	47.800	334.20	2.3400	.1822
17 LEACH OF 20 ML	32	190	45.500	311.95	2.2250	.1701
18 LEACH OF 20 ML	42	232	37.600	293.65	1.8300	.1601
19 LEACH OF 20 ML	31	263	24.600	281.85	1.1800	.1537
20 LEACH OF 20 ML	68	331	36.900	263.90	1.7950	.1439
21 LEACH OF 20 ML	40	371	18.700	255.05	.8850	.1391
22 LEACH OF 20 ML	43	414	22.200	244.45	1.0600	.1333
23 LEACH OF 20 ML	76	490	31.400	229.25	1.5200	.1250
24 LEACH OF 20 ML	102	592	41.900	208.80	2.0450	.1139
25 LEACH OF 20 ML	94	686	20.700	198.95	.9850	.1085
26 LEACH OF 20 ML	28	714	8.300	195.30	.3650	.1065
27 LEACH OF 20 ML	36	750	8.100	191.75	.3550	.1046
28 LEACH OF 20 ML	332	1082	45.900	169.30	2.2450	.0923
29 LEACH OF 20 ML	87	1169	14.400	162.60	.6700	.0887
30 LEACH OF 20 ML	8	1177	25.200	150.50	1.2100	.0821
31 LEACH OF 20 ML	262	1439	17.500	142.25	.8250	.0776
32 LEACH OF 20 ML	110	1549	18.300	133.60	.8650	.0729
33 LEACH OF 20 ML	294	1843	37.900	115.15	1.8450	.0628
34 LEACH OF 20 ML	330	2173	36.600	97.35	1.7800	.0531
35 LEACH OF 20 ML	822	2995	51.000	72.35	2.5000	.0395

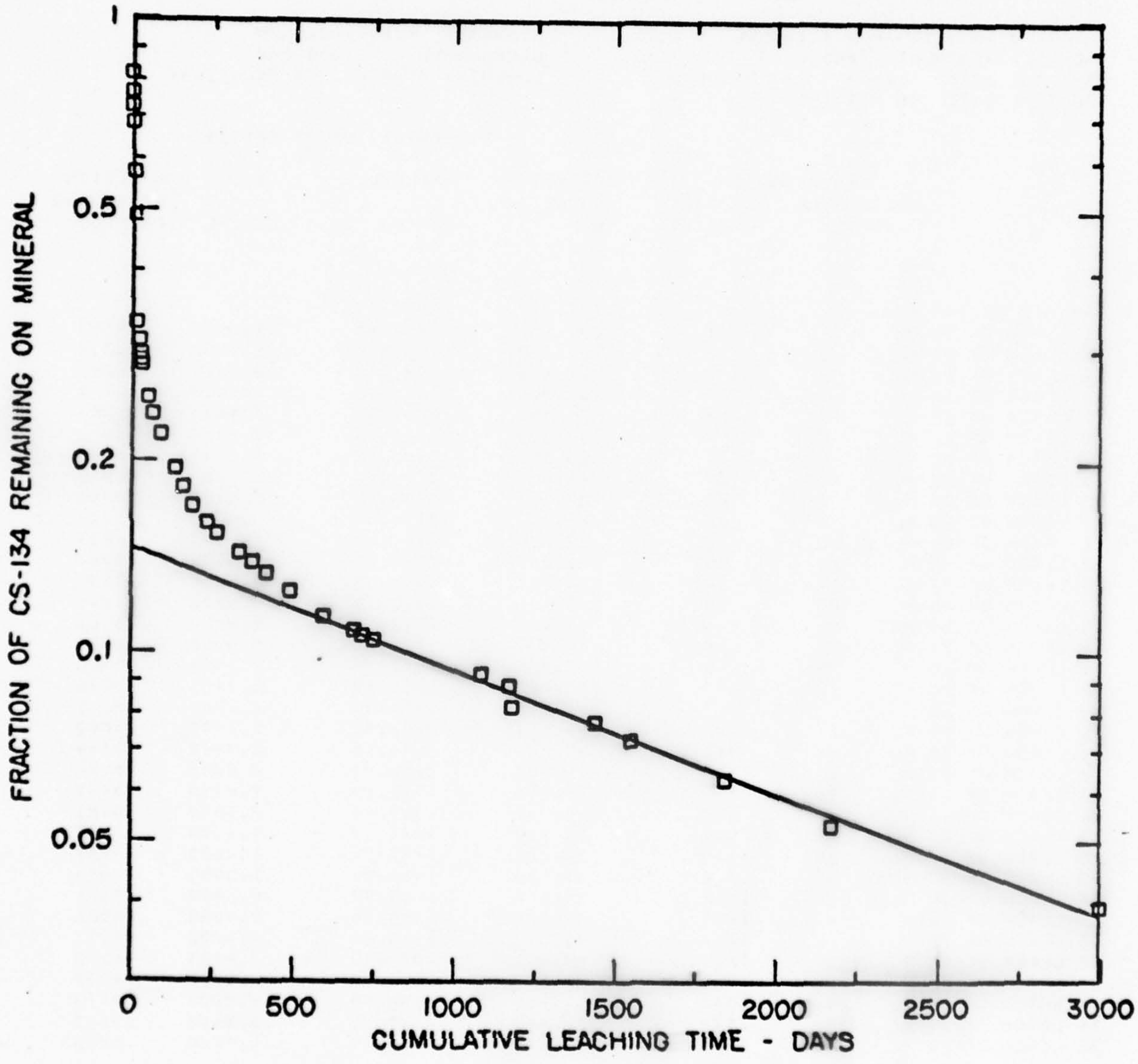

Figure 31. Leaching of Cs-134 at 900 Degrees Thermal Treatment.
Data obtained from Table 17.

Table 18

EIGHT YEAR LEACHING OF CESIUM FROM SYNTHETIC FALLOUT

LEACHING SOLUTION WAS 0.1N HCL
THERMAL TREATMENT 1200 C
PARTICLE SIZE 175 - 88 MICRONS
COUNTING DATE 16 MAY 1975

STANDARD 40000.000 C/M
BACKGROUND 1.000 C/M
LEACHING STARTED 6 FEB. 1967

CONCENTRATION OF CS-134

	LEACHING TIME		ACTIVITY	MINERAL	LIQUID	FRACTION
	DELTA TIME (DAYS)	SUM TIME (DAYS)	SAMPLE C/M	C/M/GM	C/M/ML	REMAINING CMIN/CO
MINERAL (2.000 GM)			1707.30	2597.50		
1 LEACH OF 20 ML	1	1	291.100	2452.45	14.5050	.9442
2 LEACH OF 20 ML	1	2	55.700	2425.10	2.7350	.9336
3 LEACH OF 20 ML	1	3	47.400	2401.90	2.3200	.9247
4 LEACH OF 20 ML	1	4	31.900	2386.45	1.5450	.9187
5 LEACH OF 20 ML	3	7	70.600	2351.65	3.4800	.9054
6 LEACH OF 20 ML	2	9	57.100	2323.60	2.8050	.8946
7 LEACH OF 20 ML	5	14	183.500	2232.35	9.1250	.8594
8 LEACH OF 20 ML	10	24	44.500	2210.60	2.1750	.8510
9 LEACH OF 20 ML	2	26	57.500	2182.35	2.8250	.8402
10 LEACH OF 20 ML	2	28	17.000	2174.35	.8000	.8371
11 LEACH OF 20 ML	2	30	20.600	2164.55	.9800	.8333
12 LEACH OF 20 ML	20	50	250.200	2039.95	12.4600	.7854
13 LEACH OF 20 ML	14	64	114.100	1983.40	5.6550	.7636
14 LEACH OF 20 ML	24	88	142.400	1912.70	7.0700	.7364
15 LEACH OF 20 ML	46	134	241.400	1792.50	12.0200	.6901
16 LEACH OF 20 ML	24	158	128.000	1729.00	6.3500	.6656
17 LEACH OF 20 ML	32	190	123.800	1667.60	6.1400	.6420
18 LEACH OF 20 ML	42	232	127.800	1604.20	6.3400	.6176
19 LEACH OF 20 ML	31	263	60.700	1574.35	2.9850	.6061
20 LEACH OF 20 ML	68	331	104.400	1522.65	5.1700	.5862
21 LEACH OF 20 ML	40	371	59.800	1493.25	2.9400	.5749
22 LEACH OF 20 ML	43	414	65.600	1460.95	3.2300	.5624
23 LEACH OF 20 ML	76	490	98.400	1412.25	4.8700	.5437
24 LEACH OF 20 ML	102	592	144.200	1340.65	7.1600	.5161
25 LEACH OF 20 ML	94	686	83.600	1299.35	4.1300	.5002
26 LEACH OF 20 ML	28	714	32.600	1283.55	1.5800	.4941
27 LEACH OF 20 ML	36	750	31.100	1268.50	1.5050	.4884
28 LEACH OF 20 ML	332	1082	166.200	1185.90	8.2600	.4566
29 LEACH OF 20 ML	87	1169	42.300	1165.25	2.0650	.4486
30 LEACH OF 20 ML	8	1177	91.000	1120.25	4.5000	.4313
31 LEACH OF 20 ML	262	1439	69.200	1086.15	3.4100	.4182
32 LEACH OF 20 ML	110	1549	44.800	1064.25	2.1900	.4097
33 LEACH OF 20 ML	294	1843	117.400	1006.05	5.8200	.3873
34 LEACH OF 20 ML	330	2173	118.600	947.25	5.8800	.3647
35 LEACH OF 20 ML	822	2995	189.200	853.15	9.4100	.3285

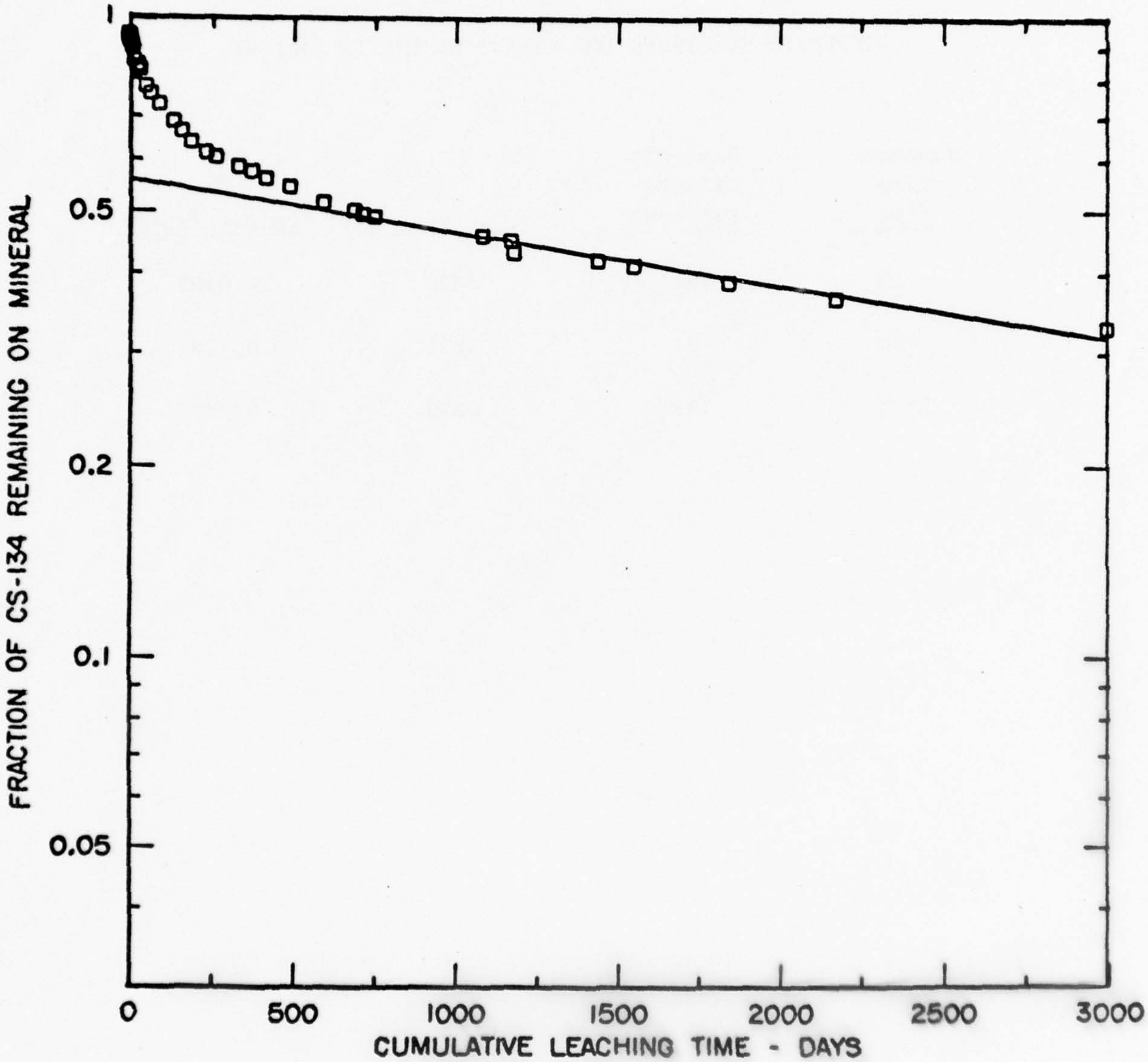

Figure 32. Leaching of Cs-134 at 1200 Degrees Thermal Treatment.
Data obtained from Table 18.

Table 19

DIFFUSION CONSTANTS FOR Cs-134 SYNTHETIC FALLOUT

Temperature (°C)	Particle Diameter (micron)	τ	D (micron^2/day)
20	101	8470	0.0305
900	101	2220	0.116
1200	101	5220	0.0495

Leaching of SHASTA Fallout

The separate leach aliquots had insufficient activity for individual counting so they were combined and counted in one tube to yield a total leaching from 17 aliquots over a period of 2,558 days. The data, which are presented in Table 21, reveal that SHASTA fallout particles were very insoluble. Generally there was little leaching except for Eu-152, which was a neutron induced radionuclide.

The SHASTA fallout particles listed in Table 3 were counted, and the data were used to compute the specific activity (c/m/g) and equivalent fissions/g as reported in Table 21.

Table 20

RADIONUCLIDE LEACHING FROM SHASTA FALLOUT

Particle*	Sb-125 Activity (c/m)	Sb-125 Leached** (%)	Cs-137 Activity (c/m)	Cs-137 Leached (%)	Eu-152 Activity (c/m)	Eu-152 Leached (%)	Eu-155 Activity (c/m)	Eu-155 Leached (%)
Magnetic								
Mineral***	6.70		180		1.80		115	
HCl	0.78	10.4	7.20	3.84	1.02	36.2	1.08	0.930
Mineral	3.00		223		3.00		152	
H_2O	.00	--	1.26	0.562	.00	--	0.360	0.236
Nonmagnetic								
Mineral	4.40		185		3.30		106	
HCl	0.480	9.84	2.76	1.46	0.840	18.6	0.780	0.730
Mineral	1.10		254		--		150	
H_2O	0.180	13.1	0.12	0.005	0.540	100	0.360	0.239

*Particle diameter 1000-500 micron.

**Combined leaching of 17 aliquots over 2,558 days.

***Fallout mineral weights in Table 4.

Table 21

RADIONUCLIDE ACTIVITY OF SHASTA FALLOUT

Particle		Sb-125		Cs-137		Eu-152		Eu-155	
Diameter (micron)	Type	Activity (c/m/g)	f* (fissions/g)	Activity (c/m/g)	f* (fissions/g)	Activity (c/m/g)	R** (152/155)	Activity (c/m/g)	f* (fissions/g)
1000-500	Magnetic	67.0	6.71 E+14	1871	3.94 E+14	41.0	1.5 E-04	1300	26.4 E+14
	Nonmagnetic	17.0	1.70 E+14	602	1.27 E+14	6.80	0.98E-04	334	6.78 E+14
500-250	Magnetic	23.0	2.30 E+14	285	0.60 E+14	6.84	1.1 E-04	300	6.09 E+14
	Nonmagnetic	0.26	0.026E+14	6.59	0.014E+14	0.18	1.9 E-04	4.57	0.093E+14
250-105	Magnetic	6.84	0.69 E+14	126	0.27 E+14	1.91	1.3 E-04	71.7	1.46 E+14
	Nonmagnetic	0.21	0.021E+14	5.83	0.012E+14	0.53	8.5 E-04	2.98	0.061E+14
105- 47	Magnetic	12.9	1.29 E+14	326	0.69 E+14	--	--	153	3.11 E+14
	Nonmagnetic	2.98	0.30 E+14	46.4	0.098E+14	--	--	46.5	0.94 E+14
< 44	Magnetic	99.4	9.95 E+14	1150	2.42 E+14	65.5	6.1 E-04	519	10.5 E+14
	Nonmagnetic	27.1	2.71 E+14	516	1.09 E+14	6.70	1.5 E-04	214	4.34 E+14

*Fissions calculated from mass chain yields reported in Dolan, P. J., "Calculated Abundances, and Activities of the Products of High Energy Neutron Fission of Uranium-238," DASA 525, May 1959 (Reference 20).

**Captures/Fission of Eu nuclides (152/155).

Leaching of SEDAN Fallout

The individual leach aliquots were also combined to yield a total leaching from 14 aliquots over 1,893 days. Only Cs-137 and Rh-102m could be measured in the SEDAN fallout. Table 22 shows that in general little was leached from the particles.

Table 22

RADIONUCLIDE LEACHING FROM SEDAN FALLOUT

Particle Diameter (micron)	Mineral 2g Leachant 20 ml	Cs-137 Activity (c/m)	Cs-137 Leached (%)	Rh-102m Activity (c/m)	Rh-102m Leached (%)	R**
2830-1410	Mineral	8.22		15.18		0.0373
	HCl	0.30	3.52	0.90	5.60	
1410- 710	Mineral	6.66		11.40		0.0377
	HCl	--	--	0.36	3.06	
350- 177	Mineral	4.38		6.90		0.0335
	HCl	0.78	15.1	1.68	19.6	
	Mineral	4.80		6.96		
	H_2O	--	--	--	--	
177- 88	Mineral	4.80		5.58		0.0237
	HCl	--	--	0.72	11.4	
	Mineral	4.20		6.42		
	H_2O	--	--	--		
88- 44	Mineral	6.36		4.14		0.0148
	HCl	2.04	24.3	0.72	14.8	
	Mineral	7.80		6.60		
	H_2O	--	--	--	--	
< 44	Mineral	13.4		3.78		0.0107
	HCl	1.14	8.00	2.04	35.1	
	Mineral	13.1		7.62		
	H_2O	1.02	7.22	--	--	

*Combined leaching from 14 aliquots over 1,893 days.
**Atoms Rh-102/fission(137).

Leaching of JOHNIE BOY Fallout

The individual leach aliquots were combined to yield a total leaching from 14 aliquots over 1,893 days. Table 23 presents the data. Co-60 was an important contributor, and it was measured along with the Cs-137, Eu-152 and Eu-155, which were also present. Eu-152 and Eu-155 appear to be the only nuclides that were appreciably leached. Significantly, the Cs-137 was tightly held by the fallout particles.

Table 24 shows the counting efficiencies that were used for the 0-2 MeV range, which was necessary to include the Co-60.

Table 25 lists the specific activity and equivalent fissions for each of the particle size ranges of JOHNIE BOY fallout as well as that for a sintered slag that was deposited in the downwind pattern.

Table 23

RADIONUCLIDE LEACHING FROM JOHNIE BOY FALLOUT

Particle Diameter (micron)	Cs-137 Activity (c/m)	Cs-137 Leached* (%)	Eu-152 Activity (c/m)	Eu-152 Leached (%)	Eu-155 Activity (c/m)	Eu-155 Leached (%)	Co-60 Activity (c/m)	Co-60 Leached (%)
>2830**	5.28		6.42		8.76		7.68	
HCl	.16	2.94	1.22	16.0	0.00	0.00	0.00	0.00
2830-1410	7.86		19.1		19.6		16.1	
H_2O	0.00	0.00	1.98	9.40	1.26	6.03	0.120	0.74
1410- 710	10.3		11.2		12.5		7.14	
HCl	0.10	0.96	0.03	0.270	0.00	0.00	0.04	0.56
710- 350	2.70		2.52		6.48		3.30	
H_2O	0.00	0.00	0.66	20.8	0.00	0.00	0.00	0.00
350- 177	2.94		4.86		5.82		2.82	
HCl	0.00	0.00	0.54	10.0	2.34	28.7	0.00	0.00
88- 62	1.38		0.84		3.42		2.52	
HCl	0.00	0.00	0.54	39.1	0.00	0.00	0.600	19.2
62- 44	1.86		1.38		3.30		1.80	
H_2O	0.00	0.00	0.36	20.7	1.44	30.4	0.00	0.00
< 44	2.88		2.34		2.88		1.56	
HCl	0.00	0.00	0.24	9.30	1.98	40.7	0.00	0.00

*Combined leaching from 14 aliquots over 1,893 days.

**For mineral weights see Table 2.

Table 24

COUNTING EFFICIENCY FOR 0-2 MeV
(Applies to JOHNIE BOY)

Nuclide	Photon* Energy MeV	Efficiency** (c/d)	Half-life*** (days)
Cs-137	0.661	0.00964	1.096×10^4
Eu-152	0.344	0.0189	5.117×10^3
Eu-155	0.086	0.0419	1.800×10^3
Co-60	1.172	0.0037	1.921×10^3

*Characteristic photon peak used in analysis.
**Counts per disintegration.
***Half-life used in calculations.

Table 25

RADIONUCLIDE ACTIVITY OF JOHNIE BOY FALLOUT

Particle	Cs-137		Eu-152		Eu-155		Co-60	
Diameter (micron)	Activity (c/m/g)	f* (fission/g)	Activity (c/m/g)	R** (captures/f)	Activity (c/m/g)	f* (fissions/g)	Activity (c/m/g)	R*** (captures/f)
>2830	2.93	5.54E11	3.57	3.47E-3	3.87	31.7E11	4.27	22.1E-3
2830-1410	4.14	7.82E11	10.0	4.60E-3	10.3	67.2E11	8.46	21.6E-3
1410- 710	3.69	6.97E11	3.99	4.21E-3	4.48	29.1E11	2.55	15.0E-3
710- 350	1.04	1.97E11	0.97	1.84E-3	2.49	16.2E11	1.27	13.5E-3
350- 177	0.860	1.63E11	1.43	3.96E-3	1.71	11.1E11	0.830	12.8E-3
88- 62	0.660	1.25E11	0.400	1.16E-3	1.63	10.6E11	5.29	85.7E-3
62- 44	1.16	2.19E11	0.860	1.97E-3	2.06	13.4E11	1.13	14.5E-3
< 44	1.69	2.19E11	1.38	3.86E-3	1.69	11.0E11	0.920	14.4E-3
Slag	16.5	31.2E11	109	36.1E-3	14.3	92.7E11	15.38	28.5E-3

*Fissions calculated from mass chain yields reported in Dolan, P. J., "Calculated Abundances, and Activities of the Products of High Energy Neutron Fission of Uranium-238," DASA 525, May 1959 (Reference 20).

**Atoms of Eu-152 per fission (155)

***Atoms of Co-60 per fission (155

Development and Production of Fallout Simulants

Over the years, the Camp Parks hot-cell facilities, operated by SRI, have developed and expanded to satisfy the requirements of many studies sponsored by the DCPA.

Radioactive particles from 44-700 microns in diameter comprise a large fraction of local fallout from a land surface nuclear explosion. Four particle size groups, namely, 44-88, 88-175, 175-350, and 350-700 microns were produced to cover the range.

Radiotagging consists of spraying a weak acid solution of a selected radioisotope on a weighed charge of mineral particles as they are tumbled in a rotating mixer. The particles are then dried. A nonleaching synthetic fallout is produced by "fixing" the radioisotope with an overcoat of sodium silicate and fusing the sodium silicate layer at 1093°C to seal in the radionuclide.

Facilities are available for producing gram, pound, or ton quantities of synthetic fallout, tagged with microcurie, millicurie, or curie amounts of radioactivity.

Two hot-cells are available for handling curie amounts of radioisotopes. One cell is fitted with a pair of Model 8 Hevi-Duty Master Slave manipulators, and the other cell with a pair of Model 4 manipulators. Radioisotopes that have been processed include: kilocuries of Ba-140, La-140, Pm-147, and Tl-204; multicuries of Sr-85, Sr-90, Zr-95, Nb-95, Ru-103, Ru-106, I-131, Cs-137, Ce-144, Lu-177 and Au-198; millicuries of Rb-85, Cs-134; and gross fission products.

More than 100 batches of Y-90 labeled sand were prepared to specification. For this purpose, a Sr-90 generator was installed in a shielded glove box inside the smaller hot-cell in July 1967. To meet the requirements of expanding programs, the Sr-90 activity was increased in increments

until a total of 50 curies was contained in the "cow." The Y-90 daughter was "milked" from the Sr-90 parent repeatedly, sometimes at 2-week intervals, by precipitating the strontium nitrate in nitric acid. The strontium nitrate was dissolved in 25 ml of distilled water and precipitated with 125 ml of 90 percent HNO_3. The acid solution containing the carrier-free Y-90 was filtered off and transferred to the second hot-cell, where it was evaporated to dryness and redissolved in another 25 ml of distilled water. Then 2 grams of inactive strontium nitrate was added and precipitated with 125 ml of 90 percent HNO_3, and the Y-90 acid solution was again filtered off, evaporated to dryness, and dissolved in 100 ml of 0.1 N HNO_3. About 40 curies of Y-90 was usually available at this point, and a 4 pi ionization chamber measurement of a 100 microliter aliquot determined the fraction of the 100 ml volume required for labeling a particular batch of sand. For certain very high purity requirements, the Y-90 was further processed to lower the Sr-90 impurities.

Sufficient Wedron quartz sand to meet the batch requirement was prepared by wet-sieving and Ro-Tapping to ensure that all particles were within the specified size range. The sand was added to the rotating drum of a ball mill that was operated inside the second hot-cell, and the calculated volume of carrier-free Y-90 solution was sprayed on the tumbling particles. The radioisotope-labeled sand was dried by the heat from a hot plate placed under the rotating drum. Then 10 ml of sodium silicate was sprayed into the rotating drum to overcoat the particles. After the particles were again dried, the synthetic fallout was transferred to a crucible and placed in a muffle furnace at 1066°C for one hour. The finished product was cooled, assayed, and packaged for shipment.

Very little Sr-90 was carried over in the nitric acid solution from the first precipitation because on 18 March 1974 an assay of the "cow" still showed 50 curies of Sr-90.

After six years of "milking" the Y-90 generator became inoperative and the Sr-90 was packaged and shipped to Nevada for burial as radioactive waste.

Tables 26 through 31 record the pertinent information on the synthetic fallout that was produced over the years.

Table 26

SYNTHETIC FALLOUT FOR UNIVERSITY OF CALIFORNIA AT BERKELEY

Batch	Date	Time	Weight	Particle Size (micron)	Iso-tope	Specific Activity (mCi/g)	Activity
UC- 1	2 Aug 67	0900	Carrier Free		Y-90		90 mCi
2	28 Aug 67	0900	Carrier Free		Y-90		90 mCi
3	11 Sep 67	0900	Carrier Free		Y-90		70 mCi
4	9 Oct 67	0900	Carrier Free		Y-90		120 mCi
5	20 Nov 67	0900	Carrier Free		Y-90		10 curies
6	20 Dec 67	0900	Carrier Free		Y-90		1 curie
7	7 Feb 68	0900	Carrier Free		Y-90		3 curies
8	6 Mar 68	0900	Carrier Free		Y-90		6.97 curies
9	19 Aug 68	1530	Carrier Free		Y-90		5.57 curies
10	5 Nov 68	1200	Carrier Free		Y-90		5.40 curies
11	12 Dec 68	0800	Carrier Free		Y-90		9.05 curies
12	3 Mar 69	1400	Carrier Free		Y-90		9.83 curies
13	18 Mar 69	1300	25 g		Y-90	1.30	
14	18 Mar 69	1300	25 g		Y-90	12.1	
15-1	4 Apr 69	0800	40 g		Y-90	0.17	
15-2	4 Apr 69	0800	40 g		Y-90	0.52	
15-3	4 Apr 69	0800	40 g		Y-90	2.04	
15-4	4 Apr 69	0800	40 g		Y-90	8.8	
15-5	4 Apr 69	0800	40 g		Y-90	11.1	
15-6	4 Apr 69	0800	Carrier Free		Y-90		3 curies
16-1	12 May 69	1300	500 g		Y-90	0.045	
16-2	12 May 69	1300	500 g		Y-90	0.134	
16-3	12 May 69	1300	500 g		Y-90	0.383	
16-4	12 May 69	1300	500 g		Y-90	1.13	
16-5	12 May 69	1300	500 g		Y-90	3.36	
16-6	12 May 69	1300	500 g		Y-90	10.1	
17	16 Jun 69	0800	Carrier Free		Y-90		6 curies
17-1	18 Aug 69	2110	500 g	88-175	Y-90	0.728	
17-2	18 Aug 69	2110	500 g	88-175	Y-90	1.38	
17-3	18 Aug 69	2110	500 g	88-175	Y-90	3.67	
17-4	18 Aug 69	2110	500 g	88-175	Y-90	7.59	
18	24 Feb 70	0900	Carrier Free		Y-90		5 curies
19	31 Mar 70	1115	3,500 ml		Y-90	0.097	
20	31 Mar 70	0900	Carrier Free		Y-90		5 curies
20-1	14 Apr 70	1630	750 g	88-175	Y-90	0.196	

Table 26 (continued)

Batch	Date	Time	Weight	Particle Size (micron)	Iso-tope	Specific Activity (mCi/g)	Activity
UC-20-2	14 Apr 70	1630	750 g	88-175	Y-90	0.446	
20-3	14 Apr 70	1630	750 g	88-175	Y-90	1.37	
20-4	14 Apr 70	1630	750 g	88-175	Y-90	4.66	
21-1	29 Apr 70	1430	750 g	88-175	Y-90	0.175	
21-2	29 Apr 70	1430	750 g	88-175	Y-90	0.460	
21-3	29 Apr 70	1430	750 g	88-175	Y-90	2.03	
21-4	29 Apr 70	1430	750 g	88-175	Y-90	7.43	
22-1	12 May 70	1400	750 g	88-175	Y-90	0.263	
22-2	12 May 70	1400	750 g	88-175	Y-90	0.916	
22-3	12 May 70	1400	750 g	88-175	Y-90	2.55	
22-4	12 May 70	1400	750 g	88-175	Y-90	8.07	
23	26 May 70	0915	500 ml of 0.1N HCl		Y-90		3.64 curies
24-1	8 Jun 70	0900	about 1 curie in 500 ml 0.1N HCl of Y-90				
24-2	8 Jun 70	0900	about 14 curies in 500 ml 0.1N HCl of Y-90				
25	14 Jul 70	0715	Carrier Free		Y-90		1.84 curies
26-1	4 Aug 70	1250	800 g	88-175	Y-90	0.350	
26-2	4 Aug 70	1250	800 g	88-175	Y-90	0.408	
26-3	4 Aug 70	1250	800 g	88-175	Y-90	1.08	
26-4	4 Aug 70	1250	800 g	88-175	Y-90	3.50	
26-5	4 Aug 70	1250	800 g	88-175	Y-90	8.17	
27-1	9 Sep 70	1330	800 g	88-175	Y-90	0.413	
27-2	9 Sep 70	1330	800 g	88-175	Y-90	1.31	
27-3	9 Sep 70	1330	800 g	88-175	Y-90	3.87	
27-4	9 Sep 70	1330	800 g	88-175	Y-90	8.03	
28-1	11 May 71	1345	500 g	88-175	Y-90	0.350	
28-2	11 May 71	1345	500 g	88-175	Y-90	0.825	
28-3	11 May 71	1345	500 g	88-175	Y-90	1.61	
28-4	11 May 71	1345	500 g	88-175	Y-90	3.09	
28-5	11 May 71	1345	500 g	88-175	Y-90	6.02	
28-6	11 May 71	1345	500 g	88-175	Y-90	16.7	
29-1	18 May 71	1255	500 g	88-175	Y-90	0.269	
29-2	18 May 71	1255	500 g	88-175	Y-90	0.386	
29-3	18 May 71	1255	500 g	88-175	Y-90	1.33	
29-4	18 May 71	1255	500 g	88-175	Y-90	4.53	
29-5	18 May 71	1255	500 g	88-175	Y-90	7.06	
29-6	18 May 71	1255	500 g	88-175	Y-90	18.8	
30-1	25 May 71	1325	500 g	88-175	Y-90	0.346	
30-2	25 May 71	1325	500 g	88-175	Y-90	0.829	
30-3	25 May 71	1325	500 g	88-175	Y-90	1.41	
30-4	25 May 71	1325	500 g	88-175	Y-90	2.07	

AD-A047 040 SRI INTERNATIONAL MENLO PARK CALIF F/G 18/8
FALLOUT SIMULANT DEVELOPMENT. LEACHING OF FISSION PRODUCTS FROM--ETC(U)
JUL 77 W B LANE, L B INMAN DAHC20-70-C-0394

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Table 26 (continued)

Batch	Date	Time	Weight	Particle Size (micron)	Iso-tope	Specific Activity (mCi/g)	Activity
UC-30-5	25 May 71	1325	500 g	88-175	Y-90	5.86	
30-6	25 May 71	1325	500 g	88-175	Y-90	20.5	
31-1	2 Jun 71	1335	500 g	88-175	Y-90	0.209	
31-2	2 Jun 71	1335	500 g	88-175	Y-90	0.470	
31-3	2 Jun 71	1335	500 g	88-175	Y-90	1.60	
31-4	2 Jun 71	1335	500 g	88-175	Y-90	3.27	
31-5	2 Jun 71	1335	500 g	88-175	Y-90	5.62	
31-6	2 Jun 71	1335	500 g	88-175	Y-90	21.8	
32-1	8 Jun 71	1315	500 g	88-175	Y-90	0.266	
32-2	8 Jun 71	1315	500 g	88-175	Y-90	0.290	
32-3	8 Jun 71	1315	500 g	88-175	Y-90	0.575	
32-4	8 Jun 71	1315	500 g	88-175	Y-90	1.93	
32-5	8 Jun 71	1315	500 g	88-175	Y-90	2.41	
32-6	8 Jun 71	1315	500 g	88-175	Y-90	10.1	
33-1	15 Jun 71	1330	500 g	88-175	Y-90	0.122	
33-2	15 Jun 71	1330	500 g	88-175	Y-90	0.210	
33-3	15 Jun 71	1330	500 g	88-175	Y-90	1.08	
33-4	15 Jun 71	1330	500 g	88-175	Y-90	3.30	
33-5	15 Jun 71	1330	500 g	88-175	Y-90	5.36	
33-6	15 Jun 71	1330	500 g	88-175	Y-90	13.3	
34-1	18 Apr 72	1330	500 g	88-175	Y-90	0.030	
34-2	18 Apr 72	1330	500 g	88-175	Y-90	0.132	
34-3	18 Apr 72	1330	500 g	88-175	Y-90	0.814	
34-4	18 Apr 72	1330	500 g	88-175	Y-90	2.76	
34-5	18 Apr 72	1330	500 g	88-175	Y-90	6.51	
34-6	18 Apr 72	1330	500 g	88-175	Y-90	20.7	
35-1	16 May 72	0820	700 g	88-175	Y-90	0.446	
35-2	16 May 72	0820	700 g	88-175	Y-90	1.14	
35-3	16 May 72	0820	700 g	88-175	Y-90	2.73	
35-4	16 May 72	0820	700 g	88-175	Y-90	6.65	
35-5	16 May 72	0820	700 g	88-175	Y-90	14.68	
36-1	20 Jun 72	0830	700 g	88-175	Y-90	0.514	
36-2	20 Jun 72	0830	700 g	88-175	Y-90	0.716	
36-3	20 Jun 72	0830	700 g	88-175	Y-90	2.36	
36-4	20 Jun 72	0830	700 g	88-175	Y-90	6.05	
36-5	20 Jun 72	0830	700 g	88-175	Y-90	13.9	
37-1	26 Jun 73	0920	700 g	88-175	Y-90	0.168	
37-2	26 Jun 73	0920	700 g	88-175	Y-90	0.362	

Table 26 (concluded)

Batch	Date	Time	Weight	Particle Size (micron)	Isotope	Specific Activity (mCi/g)	Activity
UC-37-3	26 Jun 73	0920	700 g	88-175	Y-90	1.44	
37-4	26 Jun 73	0920	700 g	88-175	Y-90	2.00	
37-5	26 Jun 73	0920	700 g	88-175	Y-90	5.36	
38-1	17 Jul 73	0830	700 g	88-175	Y-90	0.384	
38-2	17 Jul 73	0830	700 g	88-175	Y-90	0.924	
38-3	17 Jul 73	0830	700 g	88-175	Y-90	1.68	
38-4	17 Jul 73	0830	700 g	88-175	Y-90	6.59	
38-5	17 Jul 73	0830	700 g	88-175	Y-90	14.4	
39-1	11 Sep 73	0830	700 g	88-175	Y-90	0.016	
39-2	11 Sep 73	0830	700 g	88-175	Y-90	0.320	
39-3	11 Sep 73	0830	700 g	88-175	Y-90	0.980	
39-4	11 Sep 73	0830	700 g	88-175	Y-90	2.63	
39-5	11 Sep 73	0830	700 g	88-175	Y-90	6.10	
40	19 Mar 74	0920	1350 ml	total 4.62 curies of Y-90			
41-1	16 Apr 74	0845	700 g	88-175	Y-90	0.298	
41-2	16 Apr 74	0845	700 g	88-175	Y-90	0.500	
41-3	16 Apr 74	0845	700 g	88-175	Y-90	1.98	
41-4	16 Apr 74	0845	700 g	88-175	Y-90	3.66	
41-5	16 Apr 74	0845	700 g	88-175	Y-90	12.7	

Table 27

SYNTHETIC FALLOUT FOR UNIVERSITY OF TENNESSEE

Batch	Date	Time	Weight (g)	Particle Size (micron)	Isotope	Specific Activity
UT- 1	14 Jun 68	1500	200	88-175	Y-90	29.8 mCi/g
2	8 Jul 68	0300	400	88-175	Y-90	13.9 mCi/g
3	6 Aug 68	1530	400	88-175	Y-90	5.46 mCi/g
4	10 Sep 68	1210	400	88-175	Y-90	19.8 mCi/g
5	8 Oct 68	1030	200	88-175	Y-90	11.5 mCi/g
6	5 Nov 68	1300	200	88-175	Y-90	14.1 mCi/g
7	29 Nov 68	1200	200	88-175	Y-90	30.5,mCi/g
8	7 Jan 69	1300	200	88-175	Y-90	12.1 mCi/g
9	11 Feb 69	1400	300	88-175	Y-90	15.5 mCi/g
10	18 Mar 69	1300	300	88-175	Y-90	12.1 mCi/g
11	22 Apr 69	1330	300	88-175	Y-90	13.6 mCi/g
12	27 May 69	0800	300	88-175	Y-90	11.2 mCi/g
13	1 Jul 69	0830	600	88-175	Y-90	12.7 mCi/g
14	12 Aug 69	0900	600	88-175	Y-90	13.2 mCi/g
15	16 Sep 69	0810	600	88-175	Y-90	12.1 mCi/g
16	21 Oct 70	0800	600	88-175	Y-90	9.08 mCi/g
17	9 Dec 70	0800	600	88-175	Y-90	3.08 mCi/g (low--not shipped)
18	13 Jan 71	0730	[illegible]	88-175	Y-90	12.1 mCi/g
19	24 Feb 71	0730	600	88-175	Y-90	17.1 mCi/g
20	7 Apr 71	0800	600	88-175	Y-90	12.5 mCi/g
21	26 May 70	0740	600	88-175	Y-90	15.9 mCi/g
22	14 Jul 70	0730	600	88-175	Y-90	14.9 mCi/g
23	25 Aug 70	0815	600	88-175	Y-90	15.8 mCi/g
24	6 Oct 70	0900	300	44- 88	Y-90	10.7 mCi/g
					Sc-46	1.36 μCi/g
25	1 Dec 70	0945	300	44- 88	Y-90	11.2 mCi/g
					Sc-46	1.5 μCi/g
25-1	1 Dec 70	0945	600	44- 88	Sc-46	1.5 μCi/g
26	12 Jan 71	0830	300	88-175	Y-90	22.8 mCi/g
					Sc-46	1.9 μCi/g
26-1	12 Jan 71	0830	500	88-175	Sc-46	1.9 μCi/g
27	2 Nov 71	0845	300	88-175	Y-90	19.2 mCi/g
					Sc-46	1.7 μCi/g

Table 27 (concluded)

Batch	Date	Time	Weight (g)	Particle Size (micron)	Isotope	Specific Activity
UT-27-1	2 Nov 71	0845	100	88-175	Sc-46	1.7 μCi/g
28	17 Aug 71	0635	600	88-175	Y-90	17.6 mCi
					Sc-46	1.16 μCi
			300	88-175	Sc-46	1.16 μCi
29	31 Aug 71	0800	600	88-175	Y-90	17.5 mCi
					Sc-46	2.32 μCi
			300	88-175	Sc-46	2.32 μCi
30	19 Oct 71	0830	600	88-175	Y-90	19.9 mCi/g
					Sc-46	0.85 μCi/g
			300	88-175	Sc-46	0.85 μCi/g
31	30 Nov 71	0800	600	88-175	Y-90	15.3 mCi/g
					Sc-46	0.095 μCi/g
			300	88-175	Sc-46	0.095 μCi/g
32	25 Jan 72	0845	700	88-175	Y-90	18.0 mCi/g
33	14 Nov 72	0730	700	88-175	Y-90	14.3 mCi/g
34	2 May 72	0745	800	88-175	Y-90	16.8 mCi/g
35	6 Jun 72	0800	800	88-175	Y-90	18.7 mCi/g
36	18 Sep 72	0830	800	88-175	Y-90	15.3 mCi/g
37	5 Dec 72	0730	800	88-175	Y-90	13.4 mCi/g
38	7 May 73	0800	600	88-175	Y-90	18.8 mCi/g
39	24 Jul 73	0800	800	88-175	Y-90	15.2 mCi/g

Table 28

SYNTHETIC FALLOUT FOR COLORADO STATE UNIVERSITY

Batch	Date	Time	Weight	Particle Size (micron)	Isotope	Specific Activity (μCi/g)
CU- 1	15 Aug 68	0800	120 lb	88-175	Lu-177	0.091
2	13 Sep 68	0800	120 lb	175-350	Lu-177	0.088
3	15 May 69	0830	500 g	175-350	Lu-177	1.47
4	12 Jun 69	0800	20 lb	88-175	Lu-177	1.05
5	12 Jun 69	0800	20 lb	175-350	Lu-177	1.00
6	3 Jul 69	0830	20 lb	175-350	Lu-177	0.994
7	3 Jul 69	0830	20 lb	88-175	Lu-177	1.05
8	23 Jul 69	0900	20 lb	88-175	Lu-177	1.12
9	23 Jul 69	0900	20 lb	175-350	Lu-177	1.10
10	13 Aug 69	0900	20 lb	88-175	Lu-177	1.09
11	13 Aug 69	0900	20 lb	175-350	Lu-177	1.06
12	4 Sep 69	0900	20 lb	88-175	Lu-177	1.08
13	4 Sep 69	0900	20 lb	175-350	Lu-177	0.800
14	23 Sep 69	1310	20 lb	88-175	Lu-177	1.25
15	23 Sep 69	1310	20 lb	175-350	Lu-177	1.19
16	1 Dec 70	1100	480 g	88-175	Lu-177	15.1

Table 29

SYNTHETIC FALLOUT FOR NORTH CAROLINA STATE UNIVERSITY

Batch	Date	Time	Weight (g)	Particle Size (micron)	Isotope	Specific Activity (mCi/g)
NC-1	29 Jul 69	0800	500	44-88	Y-90	3.03
NC-2	29 Jul 69	0800	500	44-88	Y-90	7.78

Table 30

SYNTHETIC FALLOUT FOR CORNELL UNIVERSITY

Batch	Date	Time	Weight (g)	Particle Size (micron)	Isotope	Specific Activity (mCi/g)
CO-1	30 Jun 66	0800	185	44-63	Cs-137	0.076
2	25 Aug 66	0800	175	44-63	Sr- 85	0.202
3	9 Jan 67	0800	125	44-63	I-131	1.04

Table 31

SYNTHETIC FALLOUT FOR OAK RIDGE NATIONAL LABORATORY

Batch	Date	Time	Weight	Particle Size (micron)	Isotope	Specific Activity
OR- 1	6 Feb 67	0900	7 lb	88-175	Cs-134	1.31 μCi/g
2	6 Feb 67	0900	7 lb	88-175	Cs-134	1.34 μCi/g
3	6 Feb 67	0900	7 lb	88-175	Cs-134	2.09 μCi/g
4	20 Oct 67	0900	20 g	44- 88	Sr- 90	9.70 mCi/g
5	27 May 68	0800	160 lb	88-175	Cs-137	46.7 mCi/lb
6	27 May 68	0800	140 lb	88-175	Cs-137	36.6 mCi/lb
7	11 Mar 68	0900	30 g	88-175	Sr- 90	19 μCi/g
7(a)	11 Mar 68	0900	30 g	88-175	Sr- 90	6 μCi/g
8	25 Jun 69	0835	18 lb	44- 88	Rb- 86	4.29 μCi/g
9	25 Jun 69	0835	18 lb	88-175	Rb- 86	5.62 μCi/g

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Long term leaching studies were conducted by SRI International (formerly Stanford Research Institute) with field samples collected at SHASTA, SMALL BOY, JOHNIE BOY, and SEDAN. Fallout from each of these nuclear explosions was leached by 0.1N HCl (to represent stomach acid) and distilled water.

The leaching mechanism for the removal of eight-year-old fission products from SMALL BOY fallout by 0.1N HCl appears to be controlled by a sorption reaction for a few days, after which it is controlled by a diffusion process. Leaching of SMALL BOY fallout by 0.1N HCl removed 60% of the radioactivity from large particles and 30% from small particles. Leaching by water removed only a few percent of the radioactivity.

Generally, less than 10% of the radioactivity was removed from SHASTA, JOHNIE BOY, or SEDAN fallout by either 0.1N HCl or water.

Synthetic fallout was prepared for Defense Civil Preparedness Agency (DCPA) contractors, including the University of California at Berkeley, University of Tennessee at Oak Ridge, Colorado State University, North Carolina State University, Cornell University, and Oak Ridge National Laboratory.

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